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MULTIPLE SINUS THROMBOSIS; CEREBELLAR ABSCESS AND MENINGITIS, PROBABLY ORIGINATING FROM AN OSTEO-MYELITIS OF THE SPHENOID.

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(With two figures on Text-plate II., and a temperature chart in the text.)

Wm. M., coachman, æt. thirty-four, consulted the writer April 12, 1902.

History.—Father died many years ago from diphtheria. Mother, one brother, and four sisters living and in fair health. Personal health generally good. Eight or ten years ago had a rather large glandular swelling on one side of the neck (left?), which finally disappeared spontaneously. Many years ago had ulcer of right cornea, leaving a scar with marked impairment of vision. Four years ago, under the writer's care, had an acute suppurative otitis media of both ears, requiring paracentesis of both membranæ tympani, and running an ordinary course, the discharge altogether ceasing in two or three weeks. There had been no discharge from either ear nor aural trouble of any kind, either previously or since. Has had an atrophic rhinitis of an ordinary type for several years. For several months past has suffered at times with a severe headache not very definitely localized. Has used alcoholic liquor to excess at various times during the last four years. No history of syphilis.

Present Illness.—About three weeks previously, that is, about March 22d, the patient was taken with a severe pain in the left side of the head toward the occiput, accompanied with tenderness on pressure over the affected region, and with pronounced stiffness of the neck. There had been slight chilliness at various times, and on April 11th, the day preceding his visit, he had a severe

chill lasting an hour. The pain had been more or less severe and constant, although the patient had kept at work most of the time since the illness began.

Examination.—The skin of the left side of the neck was reddened from the domestic application of tincture of iodine a few days before. There was a marked tenderness to pressure over the posterior portion of the mastoid and over the upper portion of the posterior cervical triangle. Movements of the head occasioned pain in the posterior muscles of the left side of the neck. There was no œdema. No perceptible enlargement of the cervical glands. No tenderness on pressure over the internal jugular vein. No unusual tenderness on pressure upon the mastoid immediately back of the auricle. The membrana tympani seemed slightly reddened. Temperature 102.8°. Pulse 96. The patient was admitted to The Grace Hospital April 12th at 3 P.M.

First Operation.—Under chloroform anæsthesia the left mastoid antrum was opened. The tympanic attic and the cells of the mastoid were thoroughly explored without finding any apparent abnormality. There was neither pus nor granulation tissue. Bleeding was unduly free, rendering the exploration difficult.

Subsequent Course.—Following the operation the patient was very comfortable for about thirty-six hours. The pain in the left side of the head subsided, and the temperature fell to normal at noon of April 14th, having risen only to 100.4° on the day previous. Early in the evening of the 14th the patient was seized with a severe pain in the region of the left ear and had a pronounced chill lasting probably an hour, the temperature rising to 102°. The wound was re-dressed and inspected, but was found to be clean. The bleeding occasioned by the removal of the packing was much more free than usual. In the afternoon of April 17th the temperature rose to 104.4°, the pulse being 98, with more pain in the head. On April 17th, at 5 P.M., there was another pronounced chill, the temperature reaching 104°, with a pulse of 102, very little perspiration following. A slight chill occurred April 18th, at 2 P.M., with a temperature of 104°; pulse 98. Heretofore, outside of the local symptoms, the patient had been feeling very well, but now he began to lose strength, feeling weak and tired. At times he perspired freely, but the act of perspiration was not sensibly debilitating. After a conference with Dr. O. LeSeure, 24 grains of quinine were given in divided doses. An examination of the urine showed nothing abnormal. The diazo

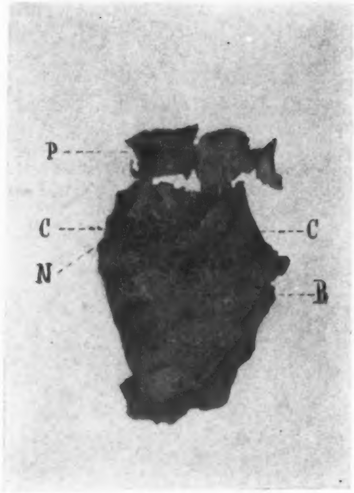
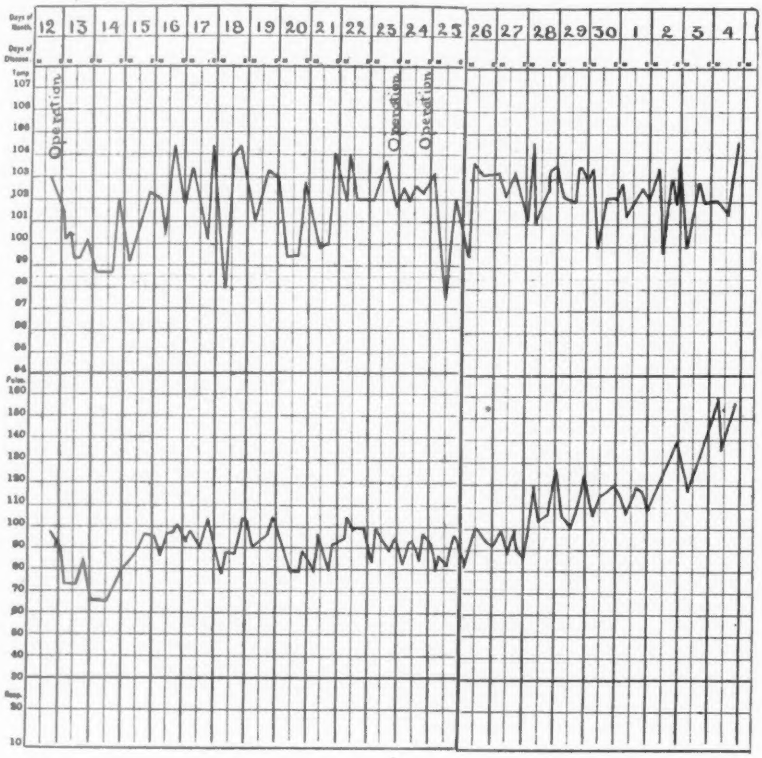


FIG. 1.—Postero-superior aspect of the body of the sphenoid. P, Posterior clinoid processes, much eroded, both having completely separated and being now merely pinned in place. C, Groove for cavernous sinus. N, Groove for sixth nerve. B, Body of the bone showing the rather extensive erosion of its surface and substance.

FIG. 2.—Inferior aspect of the brain, showing the thickened and infiltrated tissues on the left side in the neighborhood of the pons. The cross shows the location of the abscess in the cerebellum.

reaction could not be obtained. An examination of the blood for the plasmodium malariæ was negative. On the 22d Dr. Eugene Smith examined the patient at my request. Ophthalmoscopic examination in the right eye was difficult owing to the old opacity and irregularity of the cornea. Yet it was possible to affirm that there was no papillitis, and that the veins were somewhat en-



larged and tortuous. In the left eye, the outlines of the disc along its upper nasal border were obscure. No evidences of neuritis. The muscles of the neck were stiff and very painful upon motion of the head. There was marked tenderness upon pressure over the upper part of the posterior cervical triangles on both sides. No glandular swelling and no induration or tenderness along the course of either internal jugular vein. The patient had several slight chills during the previous few days. He was drowsy and slept a good deal. For a few days (even previous to the administration of quinine) there had been a somewhat

conspicuous hardness of hearing. The sitting posture caused faintness and slight gastric distress. There was no vertigo, nor any disturbances of motility beyond the general weakness. The pain in the head was not ordinarily very severe, but was now worse on the right side. The left pupil was slightly dilated and sluggish.

Second Operation.—April 23d at 5 P.M., lasting about two hours. The dressings were removed from the mastoid and the left sigmoid sinus was exposed by extending the mastoid wound backward. The sinus was exposed from the knee downward for three-quarters of an inch or more. It lay unusually deep and was reached only after considerable labor. It did not pulsate; its walls were smooth and elastic, and of a light gray color, giving no sense of hardness to the touch of a probe. An aspirating needle was then passed into the sinus and about twenty minims of fluid withdrawn, the first half of which was dark blood or bloody fluid, the last half, pus. The sinus was then opened by a slit along the entire length of the exposed portion. Upon introducing the curette, several drachms of pus escaped apparently from the bulbar end, and in curetting toward the torcular end of the sinus, free hemorrhage occurred. This soon ceased under pressure, but recurred upon the renewal of the curetting, preventing further exploration. The wound was packed with iodoform gauze. Bacteriological examination of the pus by Dr. Stricker showed staphylococcus but no streptococcus.

Following the operation, there was no essential improvement in the patient's condition. Pain and tenderness on pressure over the upper part of the right posterior cervical triangle continuing, it was resolved to explore the right sigmoid sinus.

Third Operation.—April 24th, lasting one and a half hours. The right sigmoid sinus was opened at the knee. There was no apparent thrombosis, and on opening the sinus the hemorrhage was free. The wound was accordingly packed with gauze and the patient returned to bed.

Subsequent Course.—Following this operation the condition of the patient steadily grew worse. The pain and stiffness of the neck continued. There was more or less abundant perspiration. There was a slight chill April 25th, and during the ensuing night there was an involuntary stool, small and fluid, due possibly in some measure to the saline enemas that had been given several times during the day. About twenty-four hours afterward, how-

ever, another similar involuntary stool occurred. The pain and suffering gradually diminished, the patient being constantly drowsy and sleeping much of the time. There was a slight chill on the 28th. On this date the deafness was increased. The lower half of the conjunctiva of the left eye became œdematous with a yellowish discoloration of the sclera. Upon re-dressing the wounds, about two drachms of pus escaped from the left sigmoid sinus. The chemosis of the left eye increased steadily and the eyeball began to protrude, the proptosis becoming extreme in about forty-eight hours after the conjunctival œdema was first observed. April 29th, the protrusion and swelling were so great that the upper lid could be lifted with the finger, only to a very slight extent; moreover the levator muscle of this lid was paralyzed. There was no observable paralysis of the bulbar muscles. The pupil was not much dilated but was stabile. Upon this date, three days after the first appearance of chemosis in the left eye, the upper lid of the right eye showed a beginning œdema. Stools were small, very relaxed, and frequent. At times there was a slight delirium. No retraction of the head or yawning. Nourishment was generally refused, although small quantities of milk were occasionally taken. There was occasional twitching and jerking of the extremities, especially the left hand and shoulder and the left side of the face. The patient was in a drowsy, semicomatose condition, but could be aroused and was then usually rational, although not sensible of the gravity of his condition. His speech became thick, palatal, and difficult to understand. There was also difficulty in swallowing, although there was no return of fluid through the nose when drinking. The stools and the passage of urine became involuntary. The œdema and protrusion of the right eye became moderately increased, with a yellowish discoloration of the lower half of the globe similar to that already noted in the other eye. In the left eye the œdema and proptosis lessened so that the upper lid could be easily raised with the finger, exposing the eyeball, which was fixed in position in consequence of the total ophthalmoplegia now observable. The pupil was stabile and only moderately dilated. There was now a slight loose cough with a thick frothy expectoration, without blood stain. The left frontal vein became conspicuously dilated, showing as a raised streak extending from the inner angle of the left orbit obliquely upward and inward. Respiration was regular but oral and noisy, becoming more and more rapid, rising to 56 per

minute. The patient gradually grew weaker and more comatose and died May 4th, at 10 P.M.

Autopsy.—May 5th, 7 A.M. Examination restricted to head. The proptosis had disappeared. The removal of the skull-cap was difficult, owing to the firm adhesions of the dura to the bone over more or less of the entire convexity, and in spite of care, the meninges at the base of the brain were considerably lacerated. The dura mater was thickened over the cerebrum, especially along the superior longitudinal sinus. The pia was also thickened, inflamed, and adherent along the convolutions of the superior longitudinal fissure. The walls of the longitudinal fissure, over its posterior half, and the *falx cerebri* were brightly congested. The *tentorium* of the left side was inflamed and adherent. The soft tissues about the knee of the left sigmoid sinus were necrotic and thoroughly infiltrated with pus. Upon the posterior aspect of the right cerebellum, at the site of the operation on that side, the dura was reddened and infiltrated. The entire lower surface of the brain lying in the middle fossa, was bathed with a thick, creamy pus, which was abundant and pervasive. So much of this pus escaped upon removing the brain from the skull, that it was impossible to determine with accuracy its original limits. However, it was evident that the sigmoid, superior and inferior petrosal and cavernous sinuses of the left side, the cavernous, superior and (probably) the inferior petrosal of the right side, together with the circular and transverse sinuses, were filled with pus, and that some of the pus covering the pons, medulla, and other basilar structures was due to a suppurative basilar lepto-meningitis. The pus was offensive. There were no erosions or other bony lesions in the floor of the cranial fossæ except in the sphenoid, as will be noted a little farther on. Except for the operative openings in the two sigmoid grooves, the inner surface of both temporal bones was apparently entirely normal. There was a firm decolorized clot in the left jugular bulb; a soft clot and some blood in the right bulb; a firm organized clot in the right lateral sinus, extending from the knee $\frac{1}{2}$–$\frac{3}{4}$ in. toward the torcular; and a degenerating clot in the left lateral sinus. There was also a firm thrombus in

the anterior half of the superior longitudinal sinus, extending into a number of the adjacent contributory vessels on either side. The inferior portion of the right temporo-sphenoidal lobe was congested, with a number of dark reddish discolored spots or areas on its lower surface. Upon opening the lateral ventricles, the left choroidal plexus was found reddened and enlarged. A small abscess containing about two drachms of pus was found in the anterior inferior portion of the left lobe of the cerebellum. It was not encapsulated and was evidently of recent formation. The substance of the brain generally was not noticeably abnormal. There was no pus contained in the ventricles. The surface of the brain was not stained, so far as the writer could see, by any of the numerous thrombosed sinuses, nor was there any discoloration of the bony grooves for these sinuses.

The superior posterior portion of the body of the sphenoidal bone, the dorsum sellæ, was discolored, softened, and eroded (Fig. 1, Text-plate II). The carious degeneration was such that the posterior clinoid processes had fractured and separated from the bone in the process of removing the calvarium, and remained adherent to the dura. The body of the bone was infiltrated with pus in the neighborhood of the carious portions. The soft tissues lining the large cell beneath the pituitary body were injected upon the right side. It is uncertain as to whether the pus in this cell did not get there in the process of cutting out the piece of bone containing it. The spinal cord was not examined except at its upper end, but it appeared normal.

Remarks.—When this patient first presented himself for treatment, the history of a previous suppurative otitis media, although it had been an acute attack, and although four years had elapsed with no discharge, made it seem probable that the difficulty lay in the mastoid. It would have been better surgery perhaps to have exposed and inspected the lateral sinus when pus was not found in the antrum or mastoid cells, but the operation had been difficult and somewhat prolonged, and the hemorrhage from the wound was so profuse and annoying that it seemed wiser to postpone further explorations at the time. Subsequently, the occurrence of

chills and the remittent and variable temperature (see chart) made the diagnosis of sinus thrombosis extremely probable, so that the second operation could, and perhaps should, have been made earlier. A delay was agreed to in order to eliminate the possibility of typhoid or malarial infection. This was the more justifiable in consequence of the negative evidence as to an aural or any other definite source of infection. This lack of any apparent reason for the existence of sinus thrombosis naturally created some difficulty in accepting the diagnosis and made some process of exclusion necessary to its establishment.

The pulse was not strikingly "cerebral," but was disproportionately low when compared with the maxima of temperature, showing probably a slight increase in the pressure upon the brain.

It is a question of great interest as to the original source of infection and the precise point at which the disease began. The information furnished by the autopsy does not furnish an absolutely certain solution, but it provides the basis for an hypothesis. The body of the sphenoid bone presented the appearance of having been affected with an osteo-myelitis. Some idea of its condition may be obtained from the accompanying photograph. The conditions of the autopsy prevented a more extensive specimen being taken, but the disease seemed to be confined to the piece that was removed. The erosions were confined to the surfaces shown in the illustration; the sella turcica and the internal walls of the sphenoidal cells were smooth and normal, although the body of the bone even where it was not eroded was considerably discolored. Such a disease of the sphenoid might have originated from an infection coming from without, by way of the nasal passages, the route being a very direct one, or from an infection coming from within, from the infected sinuses lying in its immediate vicinity. There was an extensive degeneration of the dorsum sellæ, the substance of the bone being filled with pus and its surface irregularly and deeply eroded. It is probably impossible to say how long a time such a degeneration would require for its development. The breaking down of loose cancellous bone may however

take place with comparative rapidity. Between the first symptoms showing occlusion of the left cavernous sinus and the autopsy, some 9–10 days elapsed—hardly time enough for very marked destruction of the bone. If this osteitis were secondary to the thrombosis of the sinuses in its vicinity, it is reasonable to inquire why it does not more commonly occur in other cases, or why in this case it did not take place in the neighborhood of the left sigmoid sinus, in the temporal bone for example, where it was open to infection by the operative exposure of the sinus. Yet there was no visible lesion of the bony walls of the skull besides that in the sphenoid. Moreover, if the osteitis were secondary to the sinus infection, the origin of this remains unsettled.

Assuming that the osteitis were primary to the sinus infection, it is not even then easy to elucidate the precise progress of the disease. We may suppose that a suppurative osteo-myelitis of the dorsum sellæ might exist for some time without definite localizing symptoms. This patient had been ill with headache, stiffness and tenderness of the posterior cervical region, fever and chills indicative of some suppurative affection for at least three weeks (probably longer) before he was seen by the writer. Sinus infection might have first occurred in the basilar plexus, extending from there to the left inferior petrosal sinus and then occluding the left jugular bulb. The subsequent thrombosis and disintegration of the clots in the various other sinuses would then naturally be determined by their contiguity with the infected areas and by the course of the currents of blood in those vessels not yet occluded. It might seem in view of such an hypothesis that the cavernous sinuses ought to have been infected earlier than they were. The œdema and protrusion of the eyeball fix the time of this involvement pretty definitely. But the flow of blood through the petrosal sinuses being in a direction away from the cavernous and circular sinuses, might have prevented their infection until the flow was arrested by the progressive occlusion. The basilar meningitis was probably secondary and of later development.

In view of the pathological conditions revealed by the

autopsy, it seems evident that the operations performed were useless, although they were abundantly justified by the symptoms present at the time. Even had there been an exact foreknowledge of the pathological conditions present, it is improbable that any surgical means would have prevented the fatal issue.

CONTRIBUTION ON OTOGENOUS DISEASE OF THE BRAIN, MENINGES, AND VENOUS SINUSES.

(FROM PROF. KÖRNER'S CLINIC AT ROSTOCK.)

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(*Continued from page 490, Vol. XXX., of these* ARCHIVES.)

Case 44. — Mastoiditis accompanying acute suppurative otitis media in a diabetic subject. Extradural abscesses in the middle and posterior cranial fossæ, unaccompanied by symptoms. Operation. Recovery.

A male, fifty-three years old, in good health until seven years ago, when he emaciated rapidly and had every symptom of diabetes. Since then he has kept a strict diet and has about held his own, being able to follow his vocation as teacher. August 15, 1901, he was suddenly seized with severe pain in the right ear. The pain was deep seated and after several days radiated towards the temple and the neck. It was worse at night. Spontaneous rupture of the drum two days later and a free discharge of pus failed to relieve the pain. When examined August 22, 1901, at the clinic, the right ear-canal was filled with odorless pus. After cleansing the canal a sausage-like swelling of the upper posterior wall extending the entire length and reaching half-way across the canal could readily be seen. Internally it covered half of the drum. A pulsating reflex indicated a perforation in the lower half of the drum. The patient could hear a whisper at 1½ feet. The temperature at this time was 36.7°, pulse 70. There were no

symptoms to indicate brain or meningeal complications. The urine contained 11.5 per cent. of sugar; no albumen.

The acute pain and otorrhœa of six weeks' standing with the unusually large swelling of the upper-posterior wall of the ear canal left little doubt of the diagnosis of acute mastoiditis, so that an operation was decided on. The exposed mastoid showed several bleeding points but no discoloration of bone. The chisel was applied over the region of the antrum. Removal of a thin cortex exposed a very vascular diploë. Pneumatic cells were only found near the antrum, and they were filled with thick polypoid mucous membrane and pus. The intervening trabeculi of bone had softened. The antrum was filled with pus. The tegmen antri had been entirely destroyed, and pus was discharging from between the dura and the bone above the opening. The dura was covered with granulation tissue. From the antrum a fistulous tract led into the swelling of the upper ear-canal, which contained pus. The hyperæmic diploë of the mastoid extended back as far as the sigmoid groove. This contained pus which had separated the lateral sinus from the groove. The sinus and the dura of the middle cranial fossa were exposed as far as they were covered with granulation tissue.

This case made a rapid recovery. In fourteen days the perforation in the drum had closed, and thirty-three days after the operation the entire wound had cicatrized. The patient was on a strict diet during the period of after-treatment.

This is the sixth case of mastoiditis observed by Körner in diabetic subjects and the fifth one upon which he has operated.

Case 45.—Perisinuous abscess the result of mastoiditis occurring in subacute middle-ear inflammation. Abducent paralysis and a marked choked disc in both eyes occurring simultaneously after evacuation of the abscess. Recovery.

A female, twelve years old, gave a history of repeated attacks of tonsillitis and gradual loss of hearing. During the latter part of March, 1901, the right ear began to discharge pus. A few days later she began to complain of nausea and had frequent attacks of vomiting. These symptoms persisted and were present when she presented herself for treatment on April 9th. On April 7th a rather firm swelling appeared behind the ear, displacing the auricle forward. When admitted to the clinic, the mastoid bone was

sensitive to pressure through the swelling. Pus discharge from the ear was so copious that the canal refilled rapidly after cleansing, making a study of the condition of the drum impossible. The patient was operated upon at once. On exposing the mastoid, granulations were found perforating the cortex over the region of the antrum. Upon enlarging this opening, the chisel came almost at once upon the lateral sinus, which was covered with granulation tissue. The entire bone was soft, the granulation tissue extending as far as the antrum, which was full of granulation and pus. All diseased structure was removed. The eyes, examined a few hours after the operation, showed normal fundi. The patient made a good though rather slow recovery, the wound closing by May 25th. During the healing, the temperature never rose above 37.5°, and usually remained at 36–37°. The child's general condition improved wonderfully and she gained considerably in weight. Thirteen days after the operation some noteworthy and unusual symptoms developed, referable to the eyes. On April 22d the child complained of diplopia, and examination revealed paralysis of the right abducens muscle. An examination of the interior of the eyes was made at the same time and a neuritis found on both sides, the elevation of the disc amounting to one dioptre. Both of these conditions grew steadily worse until about the middle of May. By June 10th muscular balance was restored, and by August all evidences of inflammation of the nerve had disappeared. An examination made in November showed that the child was in an excellent condition generally—the wound of operation had left a small scar, while the drum seemed perfect. Hearing was normal. The eyes were normal, vision being perfect. There were no signs of atrophy.

Remarks.—The complication in this case is hard to account for. The lateral sinus was found covered with granulation tissue at the time of the operation, yet there were neither local nor general signs of sinus thrombosis. Had there been any change in the optic discs previous to the operation, a temporary increase of the condition subsequently would not have been unlooked for, but to have the choked disc and paralysis coming on after evacuation of the intercranial abscess while the patient was improving rapidly in every other way is a circumstance hard to explain. This case demonstrates the importance of considering the general

condition of a patient before suggesting an operation. Had Prof. Körner followed the suggestion of one of the ophthalmologists who examined this case instead of being influenced by the general improved condition of the patient, an exploratory operation to determine the cause of the choked disc would have been undertaken.

Case 46.—Mastoiditis after scarlet fever. Operation and unintentional exposure of the lateral sinus. Pyæmic fever beginning seventeen days after the operation. Ligation of the jugular and incision of the sinus. Continuance of fever and metastatic involvement of the shoulder joint. Recovery.

A boy, eight years old, while convalescing from scarlet fever was taken with severe pain in both ears. This was two weeks before he was seen at this clinic. The pain in the left ear subsided, but continued on the right side even after rupture of the drum and a free discharge of pus. No other symptoms were observed. When first seen at the clinic, the child appeared very frail and seemed about to collapse. In consequence of his condition it was almost impossible to make a thorough examination of his ear canal. From a casual examination, the upper wall of the ear canal appeared slightly swollen. The right mastoid was sensitive to pressure, especially over Bezold's groove and the emissary vein. The ear canal contained odorless muco-pus. Both submaxillary glands were enlarged. Temperature, 39.2°. Pulse, 120.

Operation Oct. 12th.—Upon exposing the mastoid, several vascular areas were seen in Bezold's groove. Removal of a very thin lamella of bone liberated pus. The cavity from which the pus exuded communicated with the antrum. This, as well as the cells along the posterior wall of the ear canal, was filled with pus. In fact, the entire mastoid process to the tip was made up of necrotic bone and pus. The bone was removed from the antrum to the tip. The lateral sinus, which was accidentally exposed, was apparently in a normal condition. The temperature soon returned to normal after the operation, though the pus discharge continued copious.

On the afternoon of Oct. 29th, the temperature suddenly rose to 40° without being preceded by a chill. By night it dropped to 38°. As it again rose to 40° on the next day the wound was examined. The exposed portion of sinus was covered with healthy

granulations. More of the bone was removed and a greater area of sinus exposed. It was soft and healthy in appearance and showed respiratory movements. Normal blood was withdrawn with an aspirator. On the two following days the temperature still rose to 40.1–40.3°. On Nov. 1st the patient complained of pain at the base of the left lung. The possibility of pyæmia with metastatic abscess formation decided us to undertake the ligation of the jugular vein. This was done just above the facial vein. Subsequently the lateral sinus was incised, but nothing was found to account for the elevation of temperature. For the next week the afternoon temperature ranged from 38.1–to 38.6°. The general condition was fairly good. On Nov. 8th there was a sudden rise in the temperature to 39.4°. The patient complained of slight pain behind the right ear, otherwise the condition had remained unaltered. The wound seemed to be in good condition. The opening in the bone was again enlarged, the cavity being extended backward. A new portion of the sinus was aspirated. The blood withdrawn was normal. The temperature was now running a course typical of pyæmia, though there had never been a chill. The child became apathetic, lost his appetite, and complained of nausea and great thirst. On Nov. 9th, the left mastoid became sensitive to pressure, and on the following day the right elbow became painful and the shoulder joint sensitive on pressure. These symptoms subsided in several days and the general condition again improved. By Nov. 17th the patient was sitting up in bed playing. The wound was healing well. The eyes, examined at this time, as well as at several previous examinations, showed normal fundi. Changes in the background of the eyes began to show themselves on Nov. 21st, when the outlines of the papillæ appeared blurred. On Nov. 23d neuritis was marked, especially in the right eye. After Nov. 23d there was a gradual decline in the temperature, and the general condition of the patient began to improve. By Dec. 22d he was able to leave the clinic, although the wound had not quite closed. His general condition was excellent. The fundi of the eyes had returned to normal, and his vision was perfect.

Remarks.—The pyæmia in this case was probably the result of traumatism to the exposed sinus. The child was nervous and fought so hard at each dressing of the wound that the sinus was exposed to more traumatism than is usual

in such cases. This probably resulted in a small marginal thrombus at the site of injury. The respiratory movement of the sinus was evidence that the vessel was nowhere completely blocked by a thrombus. The continuance of pyæmic temperature after ligation of the jugular and incision of the sinus can only be explained in one of two ways: either there was an infection through the cavernous, petrosal, or semicircular sinus to the vessels of the other side, or it took the body a long time to eliminate the fever-producing elements.

This case teaches us that the exposure of a large area of the sinus is not without danger. The exposure of a small portion for exploratory purposes is justifiable, but unnecessary exposure of a large area should be avoided.

Case 47.—Extradural abscess of the middle cranial fossa accompanying mastoiditis after acute otitis media. Recovery.

A male, forty-seven years old, was admitted for treatment June 20, 1901. He had complained of earache on the left side on April 3d, and was treated outside the clinic. There were redness and bulging of Shrapnell's membrane at the time, a serous exudate being evacuated on incision. On account of persistence of the pain paracentesis had been repeated on April 21st. After that he failed to return to his physician. When seen at our clinic for the first time he was having severe cutting pains in the left ear. The auditory canal contained a small quantity of pus. The posterior-superior wall of the canal was swollen. There was slight œdema over the mastoid and sensitiveness to pressure over Bezold's fossa. He was operated upon June 25th. The periosteum was found detached and bulging over the mastoid. Upon incision a quantity of pus discharged, which subsequently was found to be coming from a fistula in the posterior osseous ear-canal. The fistula led to a cavity in the mastoid, which extended upward as far as the necrosed tegmen. Removal of several small sequestra of bone exposed the dura, which was covered with rather firm reddish brown granulation tissue. No pulsation was visible. The fundi oculi were normal. This case made a good recovery, with restoration of function.

Case 48.—Extradural abscess of the middle cranial fossa accompanying chronic mastoiditis. Operation. Recovery.

Male, twenty-nine years old, gave history of neglected otorrhœa on left side of twenty years' standing. Since May 16th he

had suffered from severe pain in the ear, accompanied since May 23d by swelling over the mastoid. He was first seen July 1st. The ear canal contained pus, and the upper posterior wall was so swollen as to make inspection of the drum impossible. The auricle was displaced forward by an extensive swelling of the soft parts behind it. Temperature was normal; pulse, 96. Eyes normal. Upon incising the soft parts to the bone an unusual amount of very offensive, thin pus was liberated. The wound was enlarged by a section forward to the attachment of the auricle. The bone externally was normal, but the posterior osseous wall of the auditory canal contained a fistulous opening. The mastoid was sclerotic, making it difficult to locate the antrum. It was finally entered from the tympanic cavity, an atypical radical operation having been decided upon. The tegmen tympani was necrotic, an irregular defect exposing the dura covered with granulation tissue. The necrotic ossicles were removed in cleansing the tympanic cavity. The wound was packed, the secondary operation of Stacke being done later. The patient made an uninterrupted recovery.

Case 49.—Chronic mastoiditis; extradural abscess of the middle cranial fossa. Operation. Recovery.

Male, fifty-six years old, had a running ear for over a year (left), the pus at times being streaked with blood. For several days the left ear had been painful especially when masticating. The ear canal, when he reported at the clinic on August 28th, contained offensive pus. A long polypoid mass almost occluded the canal. It was removed and subjected to a microscopic examination; was found to be made up of granulation tissue containing toward the interior numerous giant cells. The giant cells surrounded a number of minute bodies whose nature could not be determined. Notwithstanding the removal of the granulation tissue, followed by frequent irrigation, pus discharge became more copious and more offensive.

On September 10th and 11th the patient had increasing headache and complained of dizziness. There was no pain on palpation of the mastoid. The temperature was normal. Eye normal.

Operation: Skin section of Stacke; bone operation of Zaufal with secondary plastic. The mastoid was sclerotic. The antrum was filled with pus and granulations, the latter being traced as far as the dura of the middle cranial fossa. Small pieces of

necrotic bone were found imbedded in the granulating mass. The tympanic cavity also contained pus and broken-down epithelium. The ossicles were missing. Improvement began at once in this man's condition after the operation. By November 13th the cavity had covered over with epithelium, with the exception of a narrow zone at the tegmen antri where granulation tissue was still exuberant. There was still a slight discharge of pus. The granulations were gradually replaced by organized connective-tissue, but it took until January for the ear to become entirely dry. The wound had by that time contracted considerably.

Remarks.—The two features of interest in connection with this case were the presence of the peculiar bodies in the polypus removed from the ear canal, and the reproduction of granulation tissue after the operation and evacuation of pus.

The bodies referred to were most likely fine structureless pieces of bone which, after having been separated from the bone, had grown into the granulating masses.

Case 50.—Chronic mastoiditis. Sinus-phlebitis. Operation. Recovery.

Male, twenty-two years old, has had otorrhœa of the left ear for seven years. On September 2d he had pain behind the left ear and vertex, and in addition on September 3d and 4th he had frequent attacks of vomiting. On September 4th, when he presented himself at this clinic, the mastoid over Bezold's groove was sensitive to pressure, though there was no œdema of the soft parts. There was some offensive pus in the ear canal and some swelling of the posterior superior wall. There was no dizziness and no emesis. The eyes were normal. In the morning the patient had a severe chill followed by a rapid rise in temperature to 39.5°. The afternoon temperature was only 36.6°.

Operation Sept. 5th.—Skin section according to Stacke. Bone operation of Zaufal with secondary plastic. Most of the mastoid was sclerotic ; towards the tip it was cancellous, the cells being filled with pus and granulation tissue. The apex of the mastoid was removed, the sinus being exposed posteriorly. In approaching the antrum a sequestrum of bone was removed. The antrum and tympanic cavity were lined with epithelium and

granulation tissue. The sinus was bared to its knee, where softened bone was found resting against the sinus.

The sinus appeared discolored grayish red. An exploratory incision brought normal blood. The emissary vein, which was accidentally wounded, discharged blood in an intermittent stream. The temperature, which on the day of the operation rose to 38°, fell rapidly after the operation, the patient making an uneventful recovery. He was discharged cured December 3d.

Remarks.—We felt in this case that the rapid rise in temperature to 39.5° following a chill, and the circumscribed changes in the sinus, justified an exploratory incision into the vein. As the blood withdrawn was perfectly normal, we assume that removal of the necrosed bone about the sinus brought about the relief in this case. The pulsation noticed in the wounded emissary vein was an unusual condition, the significance of which could not be explained.

The next three cases are mentioned only by title, as follows:

CASE 51.—Sch. Wenbula, nine years. Chronic mastoiditis. Symptoms of leptomeningitis. Operation for mastoiditis. Death.

CASE 52.—K. Else, eight months. Bilateral otitis media purulenta. Symptoms of hydrocephalus: Lumbar puncture. Flakes of pus in the otherwise clear fluid, besides diplo- and streptococcus.

CASE 53.—B. Maria, four years. Otitis med. pur. frequently recurring. Symptoms of meningitis. Lumbar puncture. Liquid under high pressure, devoid of cellular elements. Cultures remained sterile. Death.

THE USE OF THE ROTATORY BUR IN THE TREATMENT OF CHRONIC SUPPURATION OF THE MIDDLE EAR.

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IN 1894, about a year after the publication of Macewen's *Pyogenic Infective Diseases of the Brain and Spinal Cord*, Professor Körner, at the meeting of the German Otological Society in Bonn, suggested the rotatory bur, so extensively employed by Macewen, as the best instrument to smooth the bony cavity after a radical mastoid operation. The method was adopted by many otologists in Germany and was advocated by Politzer in the last edition of his text-book on otology. It may be stated that the use of the bur is not as harmless as it would appear. This is evidenced by numerous cases of necrosis of the bone surrounding the field of operation, destruction resulting from the heat generated by the rapid rotation. On account of this danger, and from the fact that in the rapidity of healing nothing is gained by having a smooth bony cavity, Körner and other former advocates of the bur in Germany have abandoned its use in dressing the bone in radical operations; although still in use, its indications are limited.

In Körner's clinic it is employed in radical operations only when it becomes necessary to open the vestibule or semicircular canals. However, it is employed in two classes of chronic cases. We use it in cases where pus production is limited to the attic and where removal of the ossicles fails to

relieve the otorrhœa. The lateral wall of the attic can readily be removed with the bur, thereby exposing the attic with its contents and enabling the surgeon to control his therapeutic measures within the cavity.

The rotatory bur is also used in those cases where superficial necrotic areas of bone are present on the inner wall or floor of the tympanic cavity. These necrotic areas are particularly frequent about the promontory. They result from various causes—most frequently from the application of caustic therapeutic agents. The bur readily removes the necrosed tissue, the bone soon returning to its normal smooth condition, and pus discharge ceasing. To avoid injury from heat it is well to stop the bur every few seconds, the interval being employed in mopping away blood.

In the last year nine cases have been operated upon with the bur in this clinic. In four of this number the attic was exposed. Two of them were cured rapidly and have remained so until now—a period of three and a half years. The other two discontinued treatment before a cure was effected.

In all of these cases otorrhœa had existed for five years notwithstanding treatment. In the five other cases the bur was employed to remove superficial necrosed areas in the tympanic cavity. One of these cases has now been free from ear trouble for three years, one for nine months, and two for six months. One is still under treatment. Considering the abundance of material at our disposal, it is noticeable that the bur is of service in but a small per cent. of cases. Anatomical conditions must be favorable, *i. e.*, there must be a short, wide ear-canal allowing the use of a bur with a short shank.

The burs used in our clinic vary from a pyriform to a spherical shape and have a diameter of two to three millimetres. Their blades have a slightly spiral course and diminish in size as they approach the pole where they terminate. They have a much slower action at the pole than at the equator. This enables the operator to proceed more cautiously when using the pole, as in the removal of superficial necroses, and to work faster in entering the attic,

where the coarser part of the bur comes into play when working laterally.

General anæsthesia can usually be dispensed with when the bur is used for the removal of necrotic areas from the labyrinth wall. However, when the attic is to be opened, general anæsthesia is advisable. In this operation the bur readily penetrates the thin skin of the ear canal, making section of this tissue unnecessary. Bleeding is usually not severe, yet it takes frequent mopping to enable the operator to see distinctly. We use for this purpose gauze saturated in a solution of ferripyrin and cocaine. The field of operation should be well illuminated either with electric or reflected light. At the completion of the operation the cavity is irrigated, a tampon of gauze inserted, and a bandage applied. The only ill effect of the operation so far observed has been tinnitus, which usually subsided in several days.

The following cases would serve to illustrate the possibilities of the operation just described.

A male, twenty-five years old, with a history of otorrhœa on the right side since childhood, applied for treatment January 26, 1901. The ear canal was filled with foul pus. The drum was destroyed, the short process of the malleus alone being visible. Just under it a polypoid mass of granulation tissue was visible. The granulations were removed and an endeavor made with Hartmann's polypus forceps to remove the rest of the malleus. Only a portion of the manubrium and the short process of the malleus were removed. By February 20th, after regular irrigation, the discharge of pus had ceased, and the tympanic cavity, as far as could be seen, was covered with healthy epithelium. In June the otorrhœa returned and continued until October, when the patient again presented himself for treatment. The pus could then be seen exuding from the posterior portion of the recessus epitympanicus. No granulation tissue was visible, and the pus was free of epithelial debris. The patient could hear a whisper at one metre. Sounds from the tuning-fork on the vertex were transmitted to the affected side.

Conditions being favored by an unusually wide and short ear-canal, it was decided to expose the attic by removing its lateral wall with the bur. The operation was performed, November 20th, by Professor Körner, after irrigation of the attic through a curved

canula with sterile water, followed by alcohol; the skin and bone were penetrated in the manner previously described. A remnant of the body of the malleus and part of the incus were beautifully exposed and easily removed with forceps. As the attic contained no granulation tissue, and showed no break in the epithelial lining, it was evident that the pus had its origin in the antrum. Consequently it was decided also to enter the antrum with the bur. Two longitudinal sections were made through the soft parts of the ear canal, including the periosteum, one extending the length of the upper wall almost to the concha, the other along the inferior wall posteriorly. This tongue-shaped flap was elevated from the bone and pulled out of the canal and held there by means of artery forceps. Working with the bur through a short wide speculum, entrance was gained into the antrum by removing its anterior and external walls. The antrum was so thoroughly exposed that its most remote crevices could be seen. The cavity was lined with epithelium, but contained three or four small granulating areas on the posterior and median walls. After these were thoroughly removed with a curette, the flap of the membranous canal was replaced and held by a tampon. By December 31st, pus formation had entirely ceased. The function of the ear had been so much improved that a whisper could be heard at seventeen metres. Four months later, a small granulating area again appeared, but after its removal there was no further trouble.

The treatment of this case was facilitated by unusually favorable anatomical relations. It made a complete exposure of the entire middle ear through the auditory canal possible. The same operation could hardly have been performed with chisel and mallet.

The advantages offered the patient through this operation are, that it makes an externally visible wound unnecessary, and the rapidity of its completion thereby shortens the period of narcosis. The entire time consumed, including the anæsthesia and application of bandage, was only twenty-five minutes. It offers advantages to the surgeon in simplifying the after-treatment. By removing the external wall of the attic, the ossicles had so perfectly been exposed that their removal became a much safer and more simple matter than by the methods ordinarily employed. Judging by this case it is evident that in selected cases the exposure of

the attic by means of the rotatory bur is not only justifiable, but preferable to the methods ordinarily employed. In the latter, work is done in the dark, and at times considerable traumatism results. Dislocation of the incus into the antrum has also occurred. We realize that the method just described can not replace the present methods of removing the ossicles, but would advocate its use in those selected cases where anatomical relations will justify it.

VERTIGO.

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Translated by Dr. Arnold Knapp.

VERTIGO or, more properly speaking, vertigo of position is an erroneous conception of our relation in space. Normally we know whether we are lying down, standing upright, bent over, or are sitting down; whether we are moving forward, backward, sideways, up or down; whether we are stooping or whether we are turning, with head erect or bent over. The erroneous impressions of these positions, that is, sensations of vertigo, are expressed by changes in our bodily position, and although standing quietly and straight we may think we are bending over or inclined to one side, that we are sitting down or lying down, we may believe we are being moved in a vertical, horizontal, or lateral direction, or that we are moving in a quite indefinite manner. On the other hand, we may refer our sensations to our surroundings and it appears as if the surrounding space were moving forward or backward, that it is coming toward us or that it is turned in a certain direction; for instance, that the entire space is rotating about us vertically, or that the upper part is turned to the right or to the left or appears to incline toward or away from us. Finally, certain indefinite movements are perceived whose direction we cannot define.

The impression of our bodily relation in space is conveyed along three paths: by the eyes, through the organs of equilibrium in the labyrinth of the ear, and by the kinæsthetic sense—that is, the sensation of the skin, muscles, joints, and

viscera. Centripetal stimuli pass along these three paths which unconsciously enable us to preserve the equilibrium of the body. Along each one of these paths morbid stimuli may pass which, if they are sufficiently strong, will lead to a disturbed conception of our position in space—in other words, to vertigo.

I. First, in regard to the eyes. When we fix a definite object with our eyes, we increase the convexity of the lens by the action of the ciliary muscle in order to obtain a definite picture on the retina. We are able to estimate the distance between the fixed object and our body by the necessary impulse to innervate this muscular activity. This activity suffices to judge of the distance when seeing with one eye alone. When both eyes are used, a second muscular activity comes into play, namely, the convergence of the ocular axes, which also enables us to estimate the distance of the object. If by a morbid stimulus the pupil is contracted or dilated or the ocular axes converged, a false, even though unconscious, impression of distance or approach of space arises with ocular vertigo and nausea, unless this impression is corrected by other means.

Vertigo can be produced by placing a convex, concave, or cylindrical glass before healthy eyes, whereby exact fixation is prevented; also and still more so by the use of a prism, which, notwithstanding the uniform impulse to both sides, produces indistinct or double vision. This same condition occurs in ocular paralyses.

Cyon placed a prismatic glass before the eye of a dove. The animal could not fly, its movements were very shaky, and it fell at every step. Other doves showed peculiar pendulum-like movements of the head.

If the object to be regarded is situated laterally from the visual line the eyes must be turned in that direction. We judge of its position by the degree of ocular movement which in turn is determined by the amount of innervation supplied to the muscles. This estimation takes place through nervous processes of which we are unconscious. If the ocular muscle should be weakened, the necessarily increased innervation for its movement gives the impression of a

greater excursion, and consequently the object which is looked at appears to be situated more to the side than it really is; if the patient attempts to touch the object, his hand will pass to one side of it. His arm moves in conjunction with the innervation of the weakened muscle too far in the direction of the activity of this muscle, just as the other eye moves too far in this secondarily deviated position. The false projection of the visual field causes disunion between this and other sensations which serve as guides. The result of this disunion is the sensation which we call vertigo (ocular or visual vertigo). The nervous centres after a time can alter their activity so that the false projection with its consecutive vertigo ceases to annoy the patient. The patient may attempt to avoid diplopia by turning his head, whereby the action of the affected muscle is not called into play, or by closing the diseased eye.

Mendel writes: "One of the first symptoms of ocular paralysis is vertigo. It need not be permanent, as the central parts adapt themselves to the changed conditions. Patients with double seeing are able to correct this. All, however, do not do this, because at the moment of correction vertigo sets in. Stewert reports a case of a patient suffering from severe nystagmus who had violent attacks of vertigo. Pressure on the eyes sufficed to bring the vertigo to an immediate cessation. This shows that not only the peripheric but also the nuclear ocular muscle paralysis may give rise to vertigo. In some cases vertigo is a symptom which precedes the paralysis."

If the object observed moves away from the visual line, the eye must follow it according as its motility permits, and the head and body aid. If the head is held fast, the eyes may follow the moving object only to a certain point. Should the motion remain in the same direction for some time and rather slow—for instance, in the vertical plane,—the eyes will follow the object observed with the same rapidity up to the terminal positions of the ocular muscles and then return rapidly to the primary position without giving any visual impression, and from here again the original movement will be followed. The movements occur involuntarily.

The same course is pursued if the visual field remains stationary and the head or body is turned. In one rotation about ten spasmodic movements take place, which cease after several rotations. The same holds good for antero-posterior rotations. If the head is bent forward and rotations occur in the frontal plane of the head about the vertical axis, compensating ocular movements set in like those of rotatory nystagmus in 20° of deviation from the original direction. If the turning occurs with a certain rapidity, the eye will remain stationary in a strained position and indistinct visual impressions will be produced. Points appear as lines and lines as surfaces; the eyes no longer are able to instruct us in regard to the surrounding space and our relation to it.

The same indistinct visual impressions occur in rapid rectilinear progression of our body—in other words, horizontally, as in the steam cars, vertically in elevators or in rapid movements of the visual field, or a part of the same as a rapidly flowing stream or water-fall. If our attention is so taken up by these movements that they influence our ideas about the surroundings and these in turn are not corrected by our other senses, ocular vertigo occurs, but is absent when the impressions are corrected voluntarily or are neglected.

If these movements of the eyes are caused without associated movements of the body or of the visual field — as by stimuli produced in the body — they are called nystagmus The ocular movements in this case are projected externally and lead to the impression that space is moved in the opposite direction to the ocular movements.

If we regard with moving eyes an object remaining stationary in the visual field, it will appear to move in the same direction (Gowers). If the reflex stimulus from the labyrinth is so weak that it only causes a feeling of motion, then the surrounding space appears to move in the same direction. Should it, however, be so marked as to really produce nystagmus, then the stationary position of space appears to move past the slow ocular movements and a sensation of apparent movement in the opposite direction to the visual field is perceived.

Ocular vertigo, according to Mach, is as follows: It appears as if the visual space rotates in a secondary space which we consider immovable, although the latter is not visible. One would think that behind the visual space there is another space to which the first is always referred.

In order to examine ocular vertigo this author experimented as follows: The person to be examined sits upon a beam which is rotated horizontally. The patient is covered up by a paper box. In this rotating apparatus a paper drum, on the end of a vertical pole, is brought near the head of the observer. If this is brought to rotate for a few minutes, one believes that the objects not covered by the drum rotate in the opposite direction. Thus, again, one believes that the drum is rotating while the patient himself is quiet, but both subjective conditions often change.

If the rotating apparatus is brought into motion, the drum does not move. If the apparatus is then suddenly stopped, the drum will move slightly, and the observer will regard the moving drum as stationary, but thinks that he is being turned most rapidly in the opposite direction.

Bechterew, to show that the direction of the ocular axis has a most important influence on the visual organ of equilibrium, cites the observation that walking with the eyes strongly deviated to one side is sufficient to make one quite unsteady, and that the body will deviate to the opposite side. If we stand on one leg with closed eyes and then move the eyes rapidly in a certain direction, there will be an involuntary tendency of the body to go in the opposite direction and we are liable to fall unless the eyes are opened at the right moment. This same author believes that sight is of service to the atactic in walking, because it enables them to find a definite fixed point for the ocular axes rather than to control their movements, and thinks that the organ of equilibrium contained in the central gray matter is influenced by the mechanical disturbance of the lamina cinerea and the ventricular fluid by the movements of the optic nerve in movements of the eyeball.

No vertigo is caused by the typical chronic nystagmus of persons with diseased eyes. The importance from the stand-

point of differential diagnosis leads me to consider this more closely.

Nystagmus is a peculiar movement which, as a rule, attacks both eyes and is associated. If the movement is, as is usual, from right to left, or from above downward—a diagonal direction is unusual — the nystagmus is called oscillatory; if, however, the eyes move as if rotating about the visual axis, rotatory. Simultaneous movements of the head are sometimes made.

Nystagmus occurs in individuals who have been weak-sighted since childhood, and usually the degree of poor vision varies in the two eyes, though in individuals with perfect vision we occasionally observe nystagmus existing since childhood. A disturbance in the localization of the objects observed is not present, notwithstanding the constant ocular movements. Frequently in addition to nystagmus there is convergent strabismus. There may be a certain position of the eyes where they will be more quiet, while in other directions increased activity of motion results. Emotional excitement increases the vibrations. They occasionally diminish with age. Transitory vibrations are sometimes observed in predisposed eyes during inflammatory affections, if they are suddenly exposed to light, after irritation of the fifth nerve, etc.

The cause of nystagmus is supposed to be disturbance of innervation. It hardly seems possible to believe that it occurs in the interest of improved vision by projecting an object upon different parts of the retina. On the other hand, its presence in good-seeing eyes and its absence in a number of equally weak eyes, together with a variety of forms of motion, also speak against this.

For most cases Wilbrand's explanation, with a certain modification, seems to be more fitting. This depends upon the view that the centres in the mid-brain and cerebellum, which reflexly influence the ocular movements, are unusually active as opposed to the visual centres and the voluntary moving centres in the cerebrum. If the latter are secondary on account of primary or reflex irritations which pass from the cutaneous nerves and sensitive fibres of the tri-

geminus to the semicircular canals of the ear, to the cerebellum and the mid-brain, nystagmic movements result. In order to produce typical nystagmus it is, however, necessary to have the effort of seeing. In addition, we find that true nystagmus always is wanting in people who become blind in later years, and we find it absent in individuals who have been completely blind in youth. These, however, frequently show involuntary associated ocular movements which may be directed to the right, left, or down; but the true nystagmic contraction is absent.

According to Schmidt-Rimpler, the conjoined action of the effort to see plays a most important role in these nystagmic convulsions. By this, the involuntary movements which result from the preponderance of the reflex centres are interrupted in the interest of seeing by the voluntary efforts at fixation. This produces an antagonism between these two influences.

That the effort of seeing is not associated with nystagmic-like movements is also evident when we consider that they occur if movements of the head with closed eyes are executed.

The occurrence of nystagmus in the most varying intracranial diseases, pachymeningitis, sinus thrombosis, disseminate sclerosis, hereditary ataxia, and cerebro-spinal meningitis, shows that the point of irritation may be situated in one of many points in the reflex arc of ocular movements. An exact knowledge of its course is, therefore, essential.

The ciliary muscle is innervated by the third nerve. This same nerve supplies the muscles which move the eyeball, except the superior oblique, which is supplied by the fourth, and the external rectus, which is supplied by the sixth. These three motor nerves are stimulated, under ordinary circumstances: (1) voluntarily through the cerebral cortex; (2) involuntarily, subcortical, in unconsciousness, by stimuli which proceed from the optic nerve and co-ordinate from the opposite side. The voluntary stimulation of the oculomotor nerve takes place along this path. The central neuron fibres arise in the cerebral cortex. They make their way through the knee of the internal capsule with the general

pyramidal tract and leave the latter in the cerebral peduncle. They pass directly to the oculomotor nucleus underneath the central gray matter of the aqueduct of Sylvius in the region of the anterior quadrigeminal bodies, where they decussate in the middle line, after which they terminate in their final filaments. The nerve fibres arising from the nucleus pass first in the oculomotor nerve along the upper wall of the cavernous sinus, through the superior orbital fissure to the muscles about the eyeball.

According to Bechterew, the third nerve arises from several nuclei in the level of the anterior quadrigeminal bodies; two larger, one paired and one unpaired, and two smaller accessory pairs. The former contain the main nucleus below the anterior quadrigeminal bodies on both sides of the middle line. It is crescentic on transverse section. Laterally and ventrally it is in relation with the posterior longitudinal bundle. In the level of the middle and anterior thirds, between both principal nuclei, there are a medial unpaired nucleus and dorso-laterally the small oculomotor nuclei. The fibres for the pupil and accommodation are situated more anteriorly, and arise from the so-called anterior-superior nucleus. The posterior subdivide into a lateral group for the levator palpebræ, the superior rectus, and inferior oblique, and a median group for the internal and inferior recti.

The trochlear nerve arises in the cortex. Its central neuron passes to the knee of the internal capsule, decussates in the anterior medullary velum, and reaches the opposite trochlear nucleus, partly medially and partly dorsally to the posterior longitudinal bundle below the posterior quadrigeminal bodies behind the oculomotorius nucleus, with which the fourth nucleus appears to be connected. The trochlear nerve arising from behind the quadrigeminal bodies decussates with the one of the opposite side, passes along the ventral side, and supplies the superior oblique.

The abducent nerve passes from the cerebral cortex, decussates in the abducent nucleus, adjoins the middle line in the knee of the facial fibres below the fourth ventricle, and splits up. Then describing a slight arch, the sixth nerve—as its peripheric neuron—leaves the brain through the posterior

part of the pons between the latter and the medulla oblongata. In the cavernous sinus it is first situated above and then to the outer side of the carotid, passes through the superior orbital fissure, and joins the external rectus muscle.

Irritation of the posterior wall of the third ventricle causes accommodation, then contraction of the iris. Irritation of the transitional portion between the aqueductus Sylvii and the third ventricle produces contraction of the internal rectus. Irritation of the floor, starting anteriorly and passing backward, produces contraction of the following muscles in order: superior rectus, levator palpebræ, inferior rectus, inferior oblique.

The sixth nerve especially, of all the ocular nerves, is in relation, through a particular bundle of the fibres, with the upper olive. The nuclei of all the oculomotor nerves are connected by parts of the posterior longitudinal bundle whose posterior fibres pass to the spinal cord.

The importance of the tracts which connect the nuclei of the oculomotor nerves with the gray anterior horns of the spinal cord is probably found in the association of ocular movements with movement of the extremities.

The peripheric fibres of the optic nerve which arise in the ganglion cells of the outer and middle retinal layers find their terminal distribution in the retina. The neurons, however, situated in the internal layers, combine after leaving the retina and pass through the optic foramen to the optic tract in the chiasm, and there partly decussate. The fibres of the two optic nerves pass, for a longer or shorter space, in each optic tract to the cortex. The fibres of the long tract pass from the optic tract to the lateral geniculate body, surround this, and pass through the posterior third of the posterior arm of the internal capsule to the occipital lobe (calcarine fissure). The greater mass of the short tracts proceed to the primary optic centres—namely, the quadrigeminal bodies, the external geniculate body, and the pulvinar thalami, and there break up into cells of the third neuron. After this interruption they join the fibres of the optic radiation and pass through the posterior arm of the internal capsule to the cortex of the occipital lobe.

There is a collateral reflex from the optic centre in the corpora quadrigemini to the oculomotor nucleus.

Bechterew gives a somewhat different description as follows: The entire optic tract contains two functionally connected neurons. The anterior is formed by the large ganglion cells of the retina and from the fibres which originate in it. The latter are directed backward; they become components of the optic nerve and the chiasm and of the optic tract and break up into the ganglia of the inter- and mid-brains. The posterior neuron is represented by cells and neurites in these ganglia which distally enter in the occipital optic tract and reach the cortex of the occipital lobe in the neighborhood of the calcarine fissure.

The bundles of the optic nerve are sharply defined up to the region of the external geniculate body. At this point the coarser fibres partly enter into the formation of the capsule of the geniculate ganglion, and partly form the medullary lamina.

In man the external geniculate body is the most important optic centre, although delicate optic-nerve fibres also enter into the thalamus and the anterior quadrigeminal body. The latter were regarded by Gudden as pupillary reflex fibres. The anterior quadrigeminal bodies transmit light stimulus to the ocular muscles and to the motor sphere. These pupillary fibres after a partial decussation in the chiasm, continue for a distance in the tract, but at a point between the tuber cinereum and the oculomotor nerve, directly in front of the external geniculate body, they deviate toward the median line and then again, probably after a partial decussation, pass through the posterior segment of the thalamus and the posterior commissure to attain their centre, namely, one of the oculomotor nuclei. Behind the chiasm some fibres of the optic tract pass directly to the gray matter of the third ventricle. Perhaps optical impulses are transmitted along this way to the organ of equilibrium, near the third ventricle.

Bechterew was able to show that lesions of the third ventricle change the motility in the same manner as lesions of the semicircular canals and of the cerebellum. In both in-

stances the loss of bodily equilibrium is the immediate result, together with the onset of different forced movements and nystagmic symptoms. At the same time his experiment has shown that lesions and nerve sections in the course of the tracts passing from the above-mentioned points to the cerebellum produce this symptom complex.

It seems probable that the cerebellum receives centripetal impulses from these systems. There can be no doubt that there are independent centrifugal paths to the cerebellum, as removal of the parts of the brain situated proximally to the cerebellum, with the exception of the third ventricle and its neighboring gray masses, causes no interference with the normal bodily equilibrium.

As Bechterew has shown the presence of pupillary fibres which run in the optic nerve centrally from the tuber cinereum and that lesions of the third ventricle cause characteristic changes of the light reaction of both pupils, it seems probable that disturbances of the equilibrium depending upon a lesion of the third ventricle must be referred to a lesion of the optic-nerve fibres.

The peculiar blood supply of the oculomotor nerve nuclei is, according to Mendel, a likely cause for the production of ocular vertigo. He believes that every disturbance occurring in the central nervous system influences the ocular-muscle apparatus, as being a small and non-resisting portion. It is clear that this must have its cause principally in the circulatory apparatus.

Examinations of the relation of the blood supply to the ocular muscles give the following results. The nuclei of the ocular muscles are supplied by small delicate arteries which are branches of the posterior cerebral artery. These arteries are end arteries. They have no communicating branches nor communicate with the vascular system of the lateral parts. In addition to this peculiar condition, these arteries change from a horizontal to a vertical course. Another point of importance is this—the nuclei of the third and fourth nerves are situated below the cerebellum and both are supplied by small arteries derived from the basilar or the vertebral artery. These small blood-vessels originate at the

place where the current of the carotid joins that of the vertebral, causing interference with the currents and a retardation of the blood flow. Hence there is no part of the brain which is so poorly supplied as the nuclei of the ocular muscles in regard to blood supply, and from this fact it is apparent that every circulatory disturbance has full effect on the ocular muscles.

In anæmia of the brain following severe loss of blood, the first symptom is a blurring of the vision and vertigo. Similarly the circulation is altered when the cerebral vessels encounter changed physical conditions. If a weak person suddenly sits up in bed, the circulation becomes disturbed and the patient experiences vertigo.

II. The second nerve path by which we are instructed as regards the relation of our bodies in space is the vestibular branch of the eighth nerve. The terminal fibres end in the saccule of the vestibule and the semicircular canals as a thick-meshed structure surrounding the hair cells. These, supported by flask-shaped epithelial cells, are so arranged that their hairs project freely into the endolymphatic cavity. A cellular mass, which coagulates in the usual fluids of investigation, rests upon these cells, and at the region of the macula utriculi and sacculi (and in the lower animals at the lagena) contains crystals of lime (otoconia, otoliths), which in certain fishes are stones of one centimetre in size. Changes in the position of the head cause pressure on and dislocation of these crystals; the nerves of the two end stations are thereby stimulated and sensation in regard to the position of the head is produced. The long axis of the macula utriculi is directed from in front, up and in, backward, down and out. The diameter is about horizontal. The long diameter of the saccule is almost vertical, or, more properly, up and in to down and out. The lateral axis is antero-posterior. At its median wall there is the macula.

According to Adler, it is possible to distinguish a deflection forward or lateral of the head from that of the entire body by the lime plates of the sacculus and utriculus.

The gelatinous substance on the maculæ of the three ampullæ projects directly into the cavity and produces an ob-

struction to the passage of the endolymph in these canals. This current is produced by the fact that the fluid, owing to its heavy consistency, does not directly follow the movements of the bony canal and of the head and is consequently displaced and pushed to the wall. This has the result that the gelatinous cupola and the hairs of the neural epithelium are elevated and the nerves which surround the hair cells are stimulated and the sensation of movement is perceived.

If the movement of the head and of the semicircular canals continues somewhat longer, the power of inertness in this fluid is overcome by the adhesion to the walls and the fluid gradually assumes the same velocity of rotation, then we experience no rotation. Should all movement be suddenly arrested, the endolymph continues in its motion and forces the cupola and its hairs in the opposite direction. A sensation opposite to the original rotation is brought about although nothing of the kind is present. We are in error in regard to our relation in space and vertigo (labyrinthine) is produced.

To produce movement of the endolymph it is necessary that the head be moved in the plane of the canals.

We are instructed by the three different planes of the semicircular canals, of which there is always one on the right and one on the left side which are parallel, in regard to motions in three different directions.

Ewald, who has made the most extensive studies of the terminal organ of the eighth nerve, assumes the presence of a constant influence of the muscular apparatus of the body through the labyrinth of the same side, and has produced with stimulation by the anode and kathode (as well as by different currents in the membranous canals) an irritation reaction and a weaker retardation reaction. With the aid of a very delicate pneumatic hammer, he has shown that when pressure is exerted on the external semicircular canal of the dove when the ampullary end is closed off and the current is forced to the ampulla, a stimulus is experienced which turns the head to the opposite side; on retraction of the hammer, a weaker retardation by motions of the lymph current from the ampulla in the canal. The retardation of

the hammer causes an irritation in the anterior and posterior canals of the dove by forcing the current from the ampulla into the canal, and a retardation by forcing the current from the canal to the ampulla. All movements take place exactly in the plane of the semicircular canal.

Dreyfuss also assumes the presence of a labyrinthine tone. He experimented carefully in guinea-pigs and makes a distinction between the symptoms which follow the removal of one labyrinth in the first day and permanent ones. In the first hours, the head is turned toward the side of the missing labyrinth; nystagmus of the head toward the healthy side; eyes deviate toward the missing labyrinth; ocular nystagmus toward the healthy side; deviations and rotations to the side without the labyrinth. This ceases later on and the rotations only take place on movement.

In rotations to the healthy side, animals which have been operated on some time ago appear like healthy animals, but exhibit the concavity of the trunk toward the affected side, nystagmus of the head and eyes to the healthy side. In the opposite direction there is no concavity of the trunk on rotation but nystagmus of the head and eyes to the affected side, probably the result of simultaneous innervation of the muscles originating in both labyrinths. Horizontal rotation stimulates the labyrinth in the direction toward which it is directed and retards the other.

Flourens found that section of the left horizontal canal in the rabbit causes holding of the head to the left side after the violent movements to both sides have ceased.

I have been able to more exactly study the kind of nystagmus in two cases of operative injury to the descending part of the bony external semicircular canal, and in a case of large carious fistula in the ampullary extremity of this canal. Pressure on the probably intact membranous canal produced spasmodic movement of the eyeball to the side of the healthy labyrinth, and on violent pressure the eye would remain stationary in the corner nearest the healthy labyrinth. This movement took place together with movement of the head toward the healthy ear, and several times produced movement of the head. As in the latter the

lymph current has been forced into the ampulla, we may say that pressure on the canal has forced this current toward the end freed of its ampulla, or that every movement of the lymph of the horizontal canal brings about this same result—namely, the impression of rotation of the head toward the other ear. Other observations contradict this view, so that we cannot, from the described apparent movements and the movements of the eyes and head which have been observed, draw any conclusions as to the site of the disease. Examination of cases with labyrinthine necrosis on the rotating board may furnish important aid.

The only published observations of sequestrum of both labyrinths in man which are reported, by Gruber and Max, showed no muscular weakness, and consequently do not speak for the presence of a tonus originating in the labyrinth for man. The otological journals present but very few carefully examined cases in regard to the kind of vertigo.

After the above description of the ocular movements in a circulating visual field, we must assume that the rapid contractions are directed against the apparent movement and that the sensation of rotation is opposed to the apparent movement of the visual field ; in other words, directed in the same way as the contractions. The true turning is a combined factor and will be described later.

Lucae has observed in cases of perforation of the drum and rarefaction of the air in the auditory canal, vertigo with apparent movement of the visual field —in affection of the right ear, from right to left ; in left-ear affection, from left to right. The eyeball would be turned away from the irritated side and crossed diplopia ensued. The patient claimed that in experiments on his right ear the objects divided and a second indistinct picture was turned to the side. Another case presented the same apparent deviation. In a third, irritation of the left ear produced a subjective movement of the patient himself from right to left. In all cases the vertigo ceased on closure of the eyes. Lucae excludes any connection between the labyrinth and vertigo.

Jansen believes that spasmodic contractions following an injury to the semicircular canals always, or at least generally

tend toward the healthy ear, corresponding to the apparent rotation of the patient toward the healthy side. Sometimes the spasmodic contractions appeared on looking straight forward, or seemed, while they were frequent and well marked on looking to the healthy side, to be slow, superficial, and mild on looking to the diseased side.

Jacobson has described two cases of labyrinthine disease in which the patient noticed an oscillating movement of objects; in another patient with right-sided aural affection, he seemed to observe objects turning in a circle from left to right. Another patient became dizzy when a very loud c^4 tuning-fork was struck and held near the right ear, and objects appeared to turn from left to right, the patient himself believing that he was going to fall forward.

Nystagmus-like movements in sinus thrombosis are almost always of the same kind — namely, lateral and synchronous, horizontal and slightly rotated, or oscillatory, the movements being in the form of short or — on fixing — long and extensive contractions. These contractions usually followed looking toward the side opposed to the diseased ear. They would come on frequently immediately after passing the middle line, they would increase up to the extreme limit of the field, while turning the eyes to the extreme limit of the field on the aurally affected side would cause them to be perfectly quiet or show only oscillating movements.

Kipp observed a patient with left-sided suppuration who noticed that the objects appeared to move from left to right when he experienced vertigo; in addition there was nystagmus and crossed diplopia. On irrigating a suppurating left ear the pupils became dilated, the eyes moved at first slightly to the left then more strongly to the right, the movements being equally rapid in both directions and of the same extent.

In a case of right-sided suppuration, pressure on the mastoid process produced movement of the eyes usually to the left, then more rapidly and more extensively to the right; no movement of the visual fields, but the head seemed to turn. In the case of Jackson, pressure on the right tragus produced lateral movements of the eyes and movements of

the visual field from right to left; the return was not observed. This was associated with a sensation of falling to the left. Later on ocular movements were observed which were at first slow from left to right, then more rapidly to the right; the greatest excursion was noticed when an object was looked at above the head, the weakest, on looking at something near and below.

According to v. Stein, the disturbances of equilibrium in ear disease are characterized by the following points:

1. The disturbance is present with closed eyes in the absence of ataxia or paræsthesia.

2. With open eyes the rapid movements never reach their normal promptness or correctness and are usually hesitating and slow.

3. The disturbances are present in certain positions and in certain directions.

4. They are not equally distributed to both lower extremities; for instance, the patient can stand on the right leg but not on the left.

5. The disturbances of movement are polymorphous.

6. Rapid fatigue on motion, especially with closed eyes. A part of the so-called muscular sense is probably nothing else than unconscious sensation which continually emanates from the labyrinth to the muscles.

7. The reaction on the goniometer, the level of which is gradually made oblique.

8. Simultaneously existing diminished hearing and other aural troubles.

9. Tinnitus without diminished hearing.

10. Nasal affections.

11. Attacks of vertigo following lesions of the nerves or of the eyes.

12. On falling, the patient remains perfectly conscious though he may be at times slightly dazed.

Beside its terminal portion in the labyrinth, the vestibular nerve may become stimulated in the rest of its course. The median, anterior, vestibular roots of the eighth nerve arise in the area of the ampullæ from cells whose peripheric processes enter into the epithelium of the macula and crista

acoustica, and enter into relationship with the following nuclei in the medulla oblongata: first of all with the large-celled lateral or Deiter's nucleus, then with the nucleus described by Bechterew,—namely, the nucleus of the vestibular nerve at the lateral angle of the fourth ventricle, composed of small nerve cells,— and, most probably, with the so-called median nucleus. After entering into Deiter's nucleus, a part of the root diverges and passes within the nucleus for a distance, and gradually terminates in the form of the so-called ascending acoustic root which distally becomes lost in the region of the upper end of Burdach's nucleus.

Deiter's and Bechterew's nuclei are in connection with the central nuclei of the cerebellum, especially with the nucleus globosus and emboliformis. A number of fibres pass through the Deiter's nucleus to the abducent nucleus, others through the nucleus medialis in the depths of the formatio reticularis to the nucleus lateralis, to the motor vagus nucleus, consequently reflex vomiting; still others pass from the nucleus of Deiter along the lateral column of the cord. The entire floor and the lateral wall of the fourth ventricle can be regarded as the primary terminal station of the vestibular nerve. The median portion of the restiform body contains the descending branches of the vestibular nerve.

A (medial) tract passes from Deiter's nucleus anteriorly about the facial knee, traverses the abducent nucleus or passes behind this and finally enters the posterior long bundle, after dividing into ascending and descending branches. At the point of turning, collaterals are given off to the abducent nucleus.

Fibres pass from the vestibular nucleus of Bechterew along the median area of the posterior cerebellar peduncle to the cerebellum. To the upper side of these, passing partly between the elements of the anterior cerebellar peduncles, they approach the nucleus globosus and fastigii and apparently also the cortex of the corresponding half of the upper worm. Deiter's nucleus also sends fibres accompanying those of the vestibular nucleus in the median portion of the posterior peduncle to the cerebellum.

The other tracts are found in the anterior cerebellar

peduncle which decussate underneath the quadrigeminal plate, and after passing through the red nucleus and optic thalamus attain the cortex of the parietal and central convolutions. Fibres from the vestibular nucleus of Bechterew pass to the posterior long fasciculus of the opposite side to reach the area of the oculomotor nerve.

Karl Biehl divided the vestibular nerve within the cranial cavity. In the sheep, the vestibular and cochlear nerves travel entirely separated from their origin. In the horse, they are connected only by a thin anastomosis. Of twenty-four horses which had been operated on, Biehl succeeded in keeping only one alive for seven days. Immediately after the narcosis, rather awkward rolling movements set in. The animal endeavored to turn itself always so that it lay on the side operated upon. This effort was associated with violent nystagmus. If the animal recovered sufficiently to permit it to stand up, it would stand with legs outstretched, wavering, and was easily knocked over by a slight force from the healthy side. The head was held somewhat crooked, the operated side looked upward, and the head constantly made pendulum-like movements in the sagittal plane.

In the sheep, on touching the vestibular nerve, definite nystagmus and the symptoms of rolling are apparent. After division of this nerve, the head was immediately turned back so that the cheek of the operated side was flat against the shoulder. To this was added very marked nystagmus. The eyeball of the operated side was forced out and down, while the one on the healthy side was up and in. If the animal was placed on the ground, a rolling movement of the entire body about its long axis set in, in the direction of the injured side. If it lay on its side, it would remain quiet. The extremities of the healthy side were lengthened while those of the operated side were half flexed and easily movable. By lying on its back, the difference between the two sides was less apparent. The manége movements which appeared later, according to Biehl, were the result of the removal of the occipital lobe, made necessary in performing the operation which led to the half-sided visual disturbance.

While in this case section of the vestibular nerve resulted in rolling movements toward the injured side, a number of observers, including myself, have noted in man, on irritating the semicircular canals, rotatory movements toward the healthy side. Luciani has observed a similar phenomenon after removal of half of the cerebellum. This can be explained by the assumption that Biehl's section caused paralysis of the vestibular nerve, and that the opposite side preponderated, as is evident from the increased tension of the muscles of the healthy side.

Adler assumes the existence of an apparatus of equilibrium whose centripetal arm is the vestibular nerve, whose centre is furnished by Deiter's nucleus, and whose centrifugal arm is the connection of Deiter's nucleus with the oculomotor nucleus and the anterior horns of the cord. This usually acts below the threshold of consciousness.

This nervous tract is the one recently described by Hoesel—namely, fibres passing between Deiter's nucleus and the nucleus globosus and embolus of the cerebellum of the opposite side, which has also been described by Bechterew.

Ewald writes that it may be said that the non-acoustic functions of the labyrinth have nothing at all to do with the cerebrum. Animals without a cerebrum react in general to passive rotations as well as normal animals and, under certain conditions, better. In another place Ewald writes that the functions of the cerebellum, in a similar way as the eyes and the cerebrum, serve as congenital substitutes for the labyrinth, consequently the central parts for the non-acoustic eighth-nerve functions must therefore be sought in the head marrow. In any case we must, as my experiments have shown concerning the relations between the labyrinth and the muscular system, assume the presence of numerous connections with all muscles.

Gowers mentions, in addition to the frequent vomiting in aural vertigo as a proof of the intimate connection of the pneumogastric with the eighth nerve, the case of a patient who experienced rotatory vertigo after inhalation of tobacco smoke. He is convinced that in most cases in which vertigo appears to be produced in a definite uniform manner from

gastric disturbance a careful examination would reveal the presence of auditory defect.

The anatomical proof of this connection is to be found in the fibres which pass from Deiter's nucleus to the motor vagus nucleus.

Bilateral absence of the labyrinth produces, when the eyes are closed, almost the same symptoms as tabes. There are two cases of sequestration of both labyrinths reported in aural literature. The first, mentioned by Gruber in the report of his clinic in 1863, was that of a boy twelve years old. No mention is made of vertigo. The patient lived and apparently is well. The second case was reported by Max.[1] The kind of vertigo present is described as follows: At the moment when also the other side was affected the symptoms of defect became marked to such a degree at first that the patient was not able to make the slightest movement without running danger of falling to the right or left side. Gradually the disturbance of equilibrium diminished without disappearing entirely, as usual; a turning of the head, a rapid walk, or bending over, moreover walking in a street at dusk, were sufficient to produce attacks of vertigo. In fact, the attacks would sometimes appear without any external cause.

Observations on deaf-mutes should be mentioned at this point where, with great probability, the lesion of the vestibule can be taken for granted.

Kreidl observed the following in deaf-mutes: About 50 per cent. of all deaf-mutes show no ocular movements when placed on a horizontally rotating board. Of 63 deaf-mutes, 13 during rotation indicated by a pointer the vertical plane more or less vertically. Consequently they did not make the mistake of healthy people in regard to the direction of the vertical. A certain number were unable to stand with closed eyes on one leg or walk without staggering.

Ewald's doves, in which both labyrinths had been removed, had lost the sense of position of the head. If a cap was drawn over their eyes, the head sank from its own weight

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[1] *Wiener med. Woch.*, 1891, Nos. 48–51.

down, and the muscular sense then furnished no clue, and was insufficient to correct the false position.

III. *The Kinæsthetic Sense.* — The third sense tract by which we are instructed as regards our position in space transmits the kinæsthetic sense of the muscles, joints, and skin to the central organs. In any position of the body except the relaxed horizontal position, an exact determination of the opposing acting muscular activities is necessary, and even more so in moving in a straight line, in rotations of the body, in turnings and bendings of the trunk on stationary legs. The degree of the herewith necessary innervating impulse instructs us about the position of our body and of its parts. To a much less degree this is answered by the changed pressure in the vessels and of the blood in the various bodily positions.

Mach has attempted to show that the cutaneous impressions cannot lead to a false sensation of movement. The bare soles of the feet, after being made air-tight with lime, were fitted into two holes in the top of a box; the air in the box was then rarefied. There was experienced a severe pressure on the soles of the feet, and it seemed as if the floor below the feet were going to rise up. The sensation, however, that the entire body was being pushed up—which is of course relevant—was absent.

According to my mind, a sensation of movement is simulated, and we are in error in regard to the direction of the movement, as is often the case, even in actual movements.

The muscular sense as the source of knowledge of our bodily movements has also been examined by Mach. Deceptions by the muscular sense under ordinary circumstances are rare. Bechterew cites the experiment of Vierordt, who observed in man an increase of the normal swaying of the body on standing with closed eyes if the soles of the feet had been artificially anæsthetized, and emphasizes the statement that Romberg's symptom has nothing in common with true ataxia, if one understands the latter to be a disturbance of co-ordination of single movements. Morbid misconceptions are frequent if those tracts in the cord are disturbed along which muscular sense is transmitted to the

central organ. As reflex collaterals are given off from these tracts in the various levels of the spinal cord to the motor nerves, we are consequently able to diagnosticate the site of the disease by means of these reflexes.

The muscular sense may be disturbed by disease of the sensory peripheral nerves, and the co-ordination, or regular combined action of certain muscular groups, in a uniform function, may also be interfered with. In this peripheric sensory form of ataxia the centripetal influences reach the intact co-ordinating apparatus in an insufficient degree and regulation of the innervation of the motor fibres suffers.

According to Leube, the disturbance of co-ordination can be explained as follows: Every nerve of an extremity contains fibres from several spinal roots. In each root are collected probably the fibres for those muscles which are usually associated and co-ordinated and correspond to the synergic nerve fibres, and they also contain the ganglion cell groups of the gray spinal marrow. To these motor group areas, without doubt, sensory influences are received through collaterals which originate from the sensory root fibres, partly from the sensory fibres ascending in the antero-lateral root zone and from the cerebellar lateral tract bundle. These centripetal impulses, supplied by the sensory nerves of the skin, muscles, tendons, and joints to the motor ganglion cells, must exert a retarding (inhibiting) influence on the centrifugal motor stimuli in the pyramidal columns.

The centripetal co-ordination tract (Clark's columns) and the cerebellar lateral tract can be followed into the cerebellum. We must assume that in the posterior central part of the cerebellum there is a collecting place for the centripetal influences which are transferred to motor tracts. The preservation of the bodily equilibrium demands the conjoined activity of numerous muscles. To ensure a sufficient co-ordination, the various sensory impulses and the activity of its regulating influences must be exerted upon a greater number of motor tracts. This is only possible above the spinal cord.

These centripetal tracts are the following: The fibres

from the cells of the spinal ganglia and cell bodies of the various sensory peripheric neurons are collected together in the posterior roots. They divide into two parts; the larger one passes medially in the posterior columns, the smaller passes laterally in the posterior horns. The latter divide in a T-shape manner into ascending and descending branches, which after a short course turn at right angles and split up about the cells in the posterior horn. The stronger central part of the posterior roots travels in Burdach's columns and divides first into short branches, which again pass at right angles into the posterior horn, into the anterior horn, into the middle zone and Clark's cells, and represent reflex collaterals; secondly, in long branches which pass upward in Burdach's column, at first laterally then medially, collect in Goll's column and enter the fibres of the cervical cord. These long branches finally end in terminal trees in the gray nucleus in the upper extremity of the funiculi graciles and cuneati, from where the sensory central neurons and fibres of the lemniscus originate, which pass to the cerebral cortex, and fibres passing through the lateral portion of the posterior cerebellar peduncle to the cerebellum. An ascending bundle travels in the anterior column to the inner side of the pyramidal anterior tract. Clark's columns extend from the end of the cervical part to the lumbar enlargement; their axis-cylinder processes pass through the gray substance in the periphery of the lateral columns. Thus it is seen that the cerebellar tract originates from the gray of Clark's columns and principally in the upper part of the lumbar enlargement and in the lower dorsal segment, turns to the restiform body, passes along the corpus dentatum, and enters the anterior part of the cortex of the upper worm. This tract conducts centripetal impulses and degenerates in an ascending manner as soon as the continuity of the spinal cord is disturbed and is important as the sensory tract of co-ordination.

The antero-lateral fasciculus, Gower's lateral tract bundle, which is in direct communication with the cerebellum, seems also to have a certain importance for the preservation of equilibrium. Moreover, the intermediary fibres situated be-

tween the pyramids and the posterior horns, and the antero-marginal fibres at the level of Deiter's nucleus, and partly the fibres of the anterior column may be regarded as centrifugal cerebellar tracts which convey motor impulses from the cells of the anterior horns to the anterior roots, and finally the medio-marginal descending bundle in Goll's tract. The olivary tract, as much of it as enters in relation with the lower olive, conveys tracts for the bodily equilibrium.

The nerve cells with which the dorsal root fibres are united by means of their terminal ramifications or collaterals mark the presence of halting places of centripetal conducting paths, which reach the spinal cord with the dorsal roots and consequently can be considered as answering to reflex centres.

The muscular sense, apparently chiefly the cutaneous sensibility, is conducted in the inner fibres of the posterior roots. The conduction for motility and muscular sense does not decussate in the spinal cord but somewhat higher up, while the conduction for cutaneous sensibility crosses nearly completely in the spinal cord.

The paths for the sensation of pain are found in the lateral columns; those for the muscular sense in the posterior columns, presumably Burdach's. The centripetal tracts of the cerebellar lateral column are intimately connected in the dog with the preservation of bodily equilibrium, while section of this is usually followed by manége and rotatory movements.

Diseases of the posterior nerve roots cause loss of sensibility and total anæsthesia in the corresponding part of the body situated below the exit of the roots; sensory ataxia; diminution of reflexes with preserved motility. Sensory ataxia is possible in diseases of the posterior horns, while the muscular sense and motility are preserved. The reflexes will be somewhat interfered with.

Disease of the posterior columns produces (provided the gray matter and not the roots in toto are affected), as a rule, decided disturbance of the muscular sense, of the sense of touch, sensory ataxia.

Signs of ataxia are to be expected in disease of the anterior and lateral ground bundles, as the lateral ground bundle is a continuation of the processes from Clark's columns to the cerebellar lateral columns.

Disease of the cerebellar tract produces special disturbance of co-ordination, perhaps also disturbances in reflexes as the cerebellar lateral tract gives off collaterals in the gray substance. The motility is not disturbed.

The posterior columns are the typical area of tabes dorsalis. Degeneration of the posterior columns at the beginning affects especially the root zones of the funiculi cuneati. In other words, the following fibres entering the spinal cord through the posterior roots are involved: 1. Those which ascend in the funiculus cuneatus and farther up in Goll's columns. 2. Those passing to the Clark columns and from there in the root fibres, or collaterals ascending in the cerebellar lateral tract. 3. The reflex collaterals passing from posterior columns in the posterior horns and continuing to the anterior horns. The first mentioned of these fibre bundles, which, through interruption in the root zones of the posterior columns, are separated from their trophic centres in the spinal ganglia; consequently the tract degenerates secondarily in the direction of the brain from the site of lesion—that is, Goll's columns degenerate. Furthermore, the area of their collaterals degenerates in the posterior columns up to their own tract cells. Clark's ganglion cells and the cerebellar lateral tract fibres which originate from them do not degenerate, but the collaterals between the root zones and the funiculi cuneati and Clark's columns degenerate, in whose surroundings a striking disappearance of the fibres in the gray substance is apparent.

The ascending crossed fibres in the anterior and lateral tract ground bundle, which conduct the cutaneous and pain sense, which are trophically influenced by the tract cells of the gray substance, do not degenerate; on the other hand, those which ascend without decussating in Goll's columns, fibres which serve the muscular sense, do degenerate as they do not receive the trophic influence below the medulla

oblongata. It is not uncommon that in the beginning of the disease there is a decided contrast between the extremely slow development of the sensory disturbances of the skin on one side, and absence of tendon reflexes and pronounced co-ordination disturbances on the other. The greater part of the fibres which are used to convey the sense of touch, which presumably are in contact with the tract cells in the gray matter, and from this point ascend after having crossed in the anterior and lateral tract ground bundles, at first remain intact. The reflex collaterals which emanate from these remain intact, and consequently also the crossed cutaneous reflexes and the non-decussated, as the reflex arch is situated in all cases above the spinal cord.

In tabes, as the ganglion cells of the gray spinal matter do not usually degenerate, only the centripetal collaterals which pass to these suffer in their transmitting power. In consequence of this there is simply sensory ataxia, which is typical for tabes. The usual relaxed condition of the muscles in passive movements is regarded by Leube as a diminution of the reflex tone.

Friedreich's hereditary ataxia is a disease anatomically related to tabes, where constantly disease of the posterior columns and of the pyramidal lateral tracts is present, to which are added, in one-half of the cases, marginal degenerations and degenerations of Clark's columns and of the cerebellar lateral tracts. The symptoms are decided ataxia, which begins in the lower extremities and which later involves the upper and the speech apparatus, producing atactic dysarthria and usually nystagmus. The senses of taste, temperature, and muscle remain undisturbed. According to Leube, the reason that the latter are preserved although the posterior columns have degenerated, is to be found in the fact that in youthful patients other tracts serve for centripetal conduction. The ataxia depends upon the degeneration of the cerebellar lateral tracts and of Clark's columns, and the interference with conduction of the collaterals of the posterior columns and of the cerebellar lateral columns which serve for co-ordination.

EQUILIBRIUM TRACTS IN THE MEDULLA OBLONGATA.

If we follow the fibres which conduct co-ordination from the spinal cord through the medulla oblongata, we find in the lateral column, at the central end of the medulla oblongata, the olive appearing as a gray structure and increasing considerably in size upward. The two accessory olives are directly adjoining, the median lower and upper. The large lower olives are connected by the central tegmental tract with the basal parts of the cerebrum. The importance of the olivary cerebellar tract is to be found in the connection of the cerebellum with the spinal cord and represents the cerebello-fugal tract.

In the posterior columns there are gray nuclei connected with the posterior horns—namely, the nuclei funiculi gracilis and funiculi cuneati, with which probably the undecussated ascending sensory fibres come in contact, thence to pass between the olives through the internal arciform fibres to the opposite side, to form the so-called lemniscus layer. These are unquestionably joined by the sensory fibres which have already decussated in the spinal cord and ascend in the ground bundles of the anterior and lateral columns, so that all the sensory fibres are united in the mid-brain, especially in the region of the lemniscus.

The cerebellar lateral tract fibres maintain their position in the periphery, and in the medulla oblongata continue as the corpora restiformia, where they are augmented by fibres from the posterior columns to pass to the cerebellum.

The restiform body, in addition, receives a mass of fibres from the opposite side. The fibres of the restiform bodies are in connection with the fleece of the cerebellum, and through the latter with the connecting arm of the red nucleus and the tegmentum in the quadrigeminal region and the thalamus,—a fibre complex which probably belongs together functionally, and is of importance in determining the equilibrium of the body.

Through the pons the uncrossed pyramidal fibres which have passed from the medulla oblongata, and the frontal and temporal pontine tract fibres which are partly in contact with the ganglion cells in the pons and terminate in these,

partly cross in the middle line in the cerebral peduncles and pass by the cerebellum. Situated dorsally to these are the tegmental part of the pons, the lemniscus, also the substantia reticularis composed of medullated fibres, especially of the anterior and lateral ground bundles, numerous scattered nerve cells, and, dorsally to these, the posterior longitudinal bundle composed principally of anterior ground bundles. The latter can be easily followed to the upper quadrigeminal region. The fibres collected in them are probably peripheric nerve-root fibres, partly communicating fibres between the various ascending cranial nuclei.

In the lowest part of the pons the cerebral central fibres of the nuclei of the cranial nerves, especially of the fifth, sixth, and seventh, decussate before they come in contact with other nuclei.

Functionally the medulla oblongata serves as a conducting organ, and partly to originate certain reflex movements whose centres are contained in it. Such are the secretion of saliva, swallowing, sucking, and masticating, closure of the eyelids, dilatation of the pupils through shading the retina, and dyspnœtic conditions of the blood, the inhibitory nerves of the heart, secretion of sweat, vasomotor impulses.

The pons and medulla are supplied with blood furnished by the vertebral arteries and the unpaired vessels originating from them—namely, the basilar and anterior spinal arteries. The latter supplies the oblongata and the nuclei situated in its lower segments, and the spinal accessory and hypoglossal, while the buccal, facial, abducens, and trigeminal nuclei are supplied by the basilar. The oblongata receives further blood supply from lateral branches of the cerebral artery and the inferior and posterior cerebellar arteries and the posterior spinal arteries.

Bechterew has experimented with injuries of the olive. While injuries to the spinal cord do not produce any forced movements, deep incisions of the lateral parts of the medulla at the level of the olives cause rotatory movements of the animal about its long axis to the injured side (just as in case of division of the cerebellar peduncles), distinct rotation of the head and trunk about its long axis, so that the cheek of the

diseased side was almost directed down ; the eye of the affected side was turned down and out, the healthy up and in ; nystagmus was present on both sides toward the opposite side.

An injury of both olives causes decided staggering and wobbling of the head and of the trunk, with nystagmus. According to this author, the olive is in connection with the organ for the sense of touch. As the upper accessory olives are connected not only with the anterior acoustic nucleus but also with the nucleus of the abducent nerve, they may be regarded correctly as the centre which controls, with others, the reflex ocular movements. This is favored by the connection of the upper olives with the small brain, the tegmental nucleus, as lesions of the latter have always been followed by reflex disturbances in the position and movement of the eyes.

The form of paralysis characteristic for disease of the pons is the so-called alternating variety, in which the extremities of the opposite and the facial muscles of the same side are paralyzed. In addition to the paralysis of the extremities and the parts of the body supplied by the various cranial nerves, the affection of these centres spoken of comes into consideration in diseases of the pons and medulla. In rare cases ataxia is present owing to the involvement of the restiform bodies and the cerebellar lateral tract fibres, the posterior columns, and the fibres arising from the olive. Occasionally this is associated with vertigo which may at times be so severe as to appear almost as forced movements.

This is the first time that we encounter vertigo in following upward the sensory tracts. This is the first time that we approach two of the sensory tracts which instruct us as to the relation of our body ; namely, we have the sensations of the skin, muscles, and joints, and of the vestibularis, whose involvement from a morbid process is easily possible. Below this the kinæsthetic sense alone was involved and showed its disease objectively by ataxia.

EQUILIBRIUM TRACTS IN THE CEREBELLUM.

The fourth ventricle is covered by the cerebellum, which is composed of a central part (worm) and of two hemispheres.

The gray matter in the interior forms the so-called central cerebellar nuclei: 1, corpus dentatum; 2, nucleus tegmenti; 3, nucleus globosus; 4, nucleus emboliformis.

The cerebellar cortex consists of gray matter surrounding a central white medullary substance of the cerebellum which exists as a central medullary nucleus and is prolonged in branches toward the periphery (the arbor vitæ).

The medullary nucleus consists of three medullated masses, the so-called cerebellar peduncles. The upper, anterior cerebellar peduncles connect the cerebellum with the cerebrum; they converge, and between them support the medullary velum.

The anterior cerebellar peduncles arise partly in the cerebellar cortex, partly in the central nucleus of the cerebellum. Bechterew distinguishes four portions of the anterior cerebellar peduncle. The ventral bundle possesses no relations with the cerebellum and forms the commissure between the nuclei vestibularis of Bechterew at the lateral corner of the fourth ventricle. The dorsal bundle is in relation with the tegmental nucleus and, through it, with the superior worm, and passes, after leaving the general decussation, to the red roof nucleus. The third middle tract of fibres is distributed to the nucleus globosus and embolus and then to the cortex. The fourth fibre bundle is situated partly in the cortex and partly in the corpus dentatum. After completed decussation the anterior cerebellar peduncle enters into the red nucleus. A part of its elements divide up into branches about the cells of this nucleus. In addition to this, a continuous connection with the oculomotor nucleus of the opposite side can be demonstrated. Indirectly there is a connection with the fore-brain.

The cerebello-petal tracts — namely, the continuation of the pupillary reflex fibres by which the cerebellum becomes instructed as regards the position of the pupils and eyeballs — are transmitted in the fibres to the oculomotor nucleus. The vertigo resulting from injury to the third ventricle makes it likely that these pupillary fibres represent the cerebello-petal tracts of equilibrium.

The cerebro-cerebellar tract, which transmits the im-

pressions as to the position of our body in space and those producing the sense of our equilibrium, is conveyed in the main part of the anterior cerebellar peduncles which ascends to the cerebrum and which is continued from the red nucleus to the parietal convolutions. Accordingly a second communication between the fore-brain and the cerebellum, which passes through the cerebellar peduncles and ganglia of the pons and the cerebral fasciculus of the middle peduncle, influences the arrangements for equilibrium from the cerebral cortex.

As section of the anterior cerebellar peduncles does not cause any distinct disturbance of equilibrium, and as this represents the anatomical connection between the cerebellum and the cerebrum, Bechterew is led to believe that this region contains a centripetal tract along which the impressions which make up our sense of equilibrium attain the cortex of the cerebral hemispheres.

Circular movements, which appear after its section, are an objective expression of the sensation of vertigo, which is an immediate result of the operation. Then, if the vertigo is sufficient to become felt, the cerebellar preservation of the equilibrium remains undisturbed.

Bechterew distinguishes a spinal and a cerebral bundle in the middle cerebellar peduncle. The spinal bundle arises from the anterior and middle parts of the cerebellar cortex and is directed to the lower half of the pons where it ends in the gray matter of both halves. From this point fibres pass as the fasciculus verticalis, to the region of the nucleus reticularis, and the lateral area of the formatio reticularis, and finally to the antero-lateral ground bundles of the spinal cord. A few fibres pass from the pons to the quadrigeminal bodies with the lemniscus.

The cerebral bundle of the middle cerebellar peduncle arises from the distally superior and lateral parts of the cerebellar cortex, and, in the area of the upper worm and central nucleus, pass in the direction toward the upper half of the pons, where some of the fibres coming from the cerebrum along the median and lateral divisions of the cerebellar peduncles are interrupted.

The motor tracts from the cerebrum are joined in the ganglia of the pons by impulses emanating from the cerebellum which are conveyed in the middle cerebellar peduncles.

The posterior cerebellar peduncles consist of a lateral part — the restiform body,— in which most of the spinal tracts and the lower olivary tract pass,— namely, the cerebellar lateral tract to the cortex of the upper worm, fibres to the anterior and lateral tract nucleus and the fasciculi anterolateralis and intermedius, to the fasciculus antero-marginalis and the anterior tract ground bundle, to the funiculus cuneatus, to Goll's nucleus, and to the gray olive. The last has decussated to the greatest part.

The tracts to the cranial nerves — especially the vestibular nerve — and to the upper olive are found in the median portion of the posterior cerebellar peduncle.

The neurites of the tegmental nucleus pass to the medulla of the worm, and from here can be followed to the middle line. Some of these, especially those from the central and lateral parts of the brain, join the acoustic bundle of the cerebellum and, after giving off collaterals, accompany the latter to the vestibular nucleus.

From the tegmental nucleus in the cerebellum fibres pass, after decussating in the middle line, from the anterior cerebellar peduncles surrounding, in the middle part of the field, the posterior cerebellar peduncle direct, or through the fibres of the trapezius to the upper olive.

Bechterew found that section of the posterior cerebellar peduncle in its entire course from the olive to its entrance to the cerebellum, as well as injury to the olive of the same side and section of the corresponding acoustic nerve, always produced rolling of the animal in the direction of the side operated upon. Section of the fibres passing below the aqueduct of Sylvius, in their course from the posterior lateral wall of the third ventricle to the antero-external part of the floor of the fourth ventricle, also section of the middle cerebellar peduncles in various planes, are always accompanied by rolling movements in the direction of the opposed side.

Section of the anterior cerebellar peduncles never caused

any rolling but always circular movements with lateral deviation of the eyes, which was toward the operated side after section between the cerebellum and quadrigeminal bodies; there was deviation to the healthy side with nystagmus after section between the optic thalamus and the anterior quadrigeminal bodies.

Bechterew concludes from his experiments that the fibre bundles of the olives to the semicircular canals are conveyed in the corresponding posterior cerebellar peduncle and do not decussate up to the posterior external part of the cerebellar hemispheres. Lesions in this latter site are always followed by rolling movements toward the side operated upon.

Cerebello-petal tracts are consequently the central tracts of the vestibular branch, the cerebellar fibres to the posterior tract nuclei, the cerebellar lateral tracts, the cerebellar olivary fibres as well as the ascending antero-lateral fasciculus.

The spinal bundle of the middle peduncle is centrifugal. It is in connection, partly direct and partly through the raphe fibres, with the reticular tegmental nucleus and with the connecting arms of the formatio reticularis and the antero-lateral ground bundle of the medulla.

The centrifugal nature of the cerebellar superior olivary tract is made probable by the direct communication of the superior olives with the nuclei of the abducent nerves and their part in the mechanism of the reflex ocular movements. The cerebellar fibres passing in the anterior peduncles to the oculomotor nucleus of the opposite side have probably the same relation.

The centrifugal cerebellar tracts are the anterior marginal bundle, the fibres of the posterior longitudinal fasciculus, the intermediary bundle of the lateral tracts and part of the cerebello-olivary fibres, the spinal bundle of the middle cerebellar arm, as well as those fibre bundles of the latter which pass through the depth of the pons to the tegmental region, and finally, fibres which descend as the anterior lateral descending bundles from the cerebellum to the upper olive, to Deiter's nucleus, and in the lateral tract nuclei.

The following sensory stimuli are concentrated in the cerebellum: the sensation of muscular sense passing along the posterior columns and the posterior-column nucleus to the cerebellum, as well as the visceral sense, presumably transmitted by the cerebellar lateral tracts; the sensation of the vestibular nerve and probably of the pupillary fibres.

The cerebellum is functionally in close relation with co-ordination. It is probable that it is not directly influenced by motor tracts, but inasmuch as the varying sensory stimuli are brought together in it, a regulating influence is exercised on the innervation of the motor tracts. From its direct and indirect connection with the ganglion-cell systems of the brain, the cerebellum is enabled to control the combined activity of numerous muscles, which is necessary for maintaining the equilibrium of the body.

According to Luciani, the cerebellum may be regarded as a small aiding and strengthening apparatus for the entire cerebro-spinal system. Its destruction is shown by asthenia, atonia, and astasia (in the dog).

The experimental results are supported by the comparative study of the cortical fibres of the cerebellum in various animals. In man, the sheep, the chicken, and dove a direct correlation has been demonstrated between the development of the cerebral cortex and the acts of walking and standing. In sheep and chicken this function begins immediately after birth, and the fibres of the cerebellar cortex at this time are found to be completely medullated. In other animals, on the other hand, a successive medullation first takes place after birth.

Leube writes that injuries to the cerebellum produced in experiments cause severe permanent disturbances of co-ordination only if larger parts of the cerebellum are affected. On the other hand, deep injuries to the worm have the same effect. After one-sided superficial lesion of the restiform body nystagmus was produced, and forced rolling movements set in after lesion of the peduncle and the pons, just as in injuries of the various other parts of the central nervous system. It is distinctly to be remembered that the activity of the will and of the senses, as well as the

intelligence, is in no way interfered with by a lesion of the cerebellum.

According to Adler, the function of the cerebellum is to maintain the bodily equilibrium and to add strength and precision to movements.

Bechterew emphasizes that the symptoms appearing after injury to the cerebellum are not to be explained by simple functional destruction, but rather by want of harmony in the activity of the remaining cerebral parts.

Schiff observed, after unsymmetrical injury to the cerebral hemispheres, nystagmus of short duration, strabismus after prolonged irritation, or both combined. These symptoms remain permanent if the injury included the inter-peduncular part of the cerebellum, such as the uvula or the nodulus. In hemorrhages into the cerebellar peduncles a deviation has always appeared on the injured side, usually to one side, and the eye of the affected side shows nystagmic movements as long as the animal remains nearly or completely quiet. If the head or body is energetically moved, the nystagmus of the affected side becomes converted into a real strabismus which does not change its main direction, but has interrupted, small, convulsive movements of the eyeball.

As the vestibularis is principally connected with the cerebellum of the same side, irritation of the right cerebellum causes turning or rotation of the body from right to left, just as is noticed after irritation of the right vestibularis. This confirms Luciani's experiments. After a period of irritation following the removal of the right cerebellum, dogs made rolling movements from right to left. Nystagmus and strabismus were also found in this form.

After incomplete removal of the right cerebellum the right eye deviated always in the same direction, down and in, and was frequently associated with nystagmus in dogs and monkeys. In the latter, nystagmus was on both sides. From this it seems that the cerebellar lobes in the dog serve to represent and to perform movements about the main axis. In four dogs from whom Luciani had removed the middle lobe of the cerebellum, opisthotonos was present as an irritative symptom in varying degrees up to bending back of the

head on the spinal vertebræ, together with tonic extension movements of the anterior extremities; and in two, convergent strabismus; in two monkeys, flexion of the head and neck backward and tonic flexion of the arms were present.

In removal of only the middle lobe irritative symptoms were symmetrical. According to this, the middle lobe appears to serve for movements in the antero-posterior diameter. This corresponds to the convergent strabismus, the fixing of the eyes upon a visual field apparently brought as near as possible.

In one of Luciani's dogs, after removal of the right half of the cerebellum, the declive anterius, the lower part of the declive posterius and flocculus were uninvolved. Irritative symptoms were turning to the right in a circle about the vertical axis in the middle point of its back. The right anterior extremity was in tonic extension. In another, the monticulus, the declive posterius and pyramid were affected in the section involving the upper two-thirds of the thickness of the middle lobe, not exactly in the median line but a little to the left. Manége movements to the right resulted. In two blind dogs, notwithstanding that the right half was removed, rollings did not result, but in one there were manége movements.

In complete removal of the cerebellum Luciani observed in one case tonic convulsions of the muscles of the neck, extension of the anterior extremities; clonus of the posterior extremities in another. The eyes were widely opened, the pupils dilated, and convergent strabismus was present in two monkeys.

The incomplete removal of the cerebellar halves and of the middle lobe makes it probable that in the cerebellum, just as in the sensory and motor regions of the cerebrum, the activity of certain muscular groups is connected with certain regions, and that the sensation and performance of movements forward and backward, with dilatation and possibly contraction of the pupil, as well as convergent strabismus, are related to the middle lobe.

Rolling movements about the long axis, manége movements with nystagmus and strabismus in and down, perhaps

also nystagmus rotatorius, are connected with the lateral lobes. This is supported by the presence of an unusually well-developed middle lobe in animals that have to perform movements in a vertical direction, as fishes and birds, where the macula lagenæ is present.

The ocular movements give us a clue to the disease of various parts of the cerebellum or labyrinth and the oculomotor nerves. We must, then, examine the following:

Horizontal nystagmus to the right: involvement of the horizontal canal to the left; left cerebellar lobe, and sensation and act of rotating to the left. Rotatory nystagmus: frontal canal; sensation and action of rolling movements. Convergent strabismus: sacculus and utriculus, middle lobe, sensation and action of vertical movements forward or backward, with narrow or dilated pupils.

Perhaps it will be possible to determine the nerve tracts which connect the various individual points.

The centre for the activity of the cerebellum is sub-cortical and acts without consciousness. Frogs, rabbits, and doves, after their cerebral hemispheres are removed, can walk and stand. The same was observed in Goltz's dog without a cerebrum. Pathological experience in man shows us that epileptics, where the cerebrum is excluded, may still walk and perform motions. Löwenfeld was able to produce movements of vertigo in deeply chloroformed rabbits, also with the galvanic current in the case of sucklings which were asleep. All of these subcortical centres have their representation in the cerebrum.

An observation of Berthold favors the subcortical location of vertigo—namely, that the pendulum-like movements of the head are continuous in sleep; and another observation of Gowers, that a patient in sleep bent himself so that his head projected over the edge of the bed or came to lie next to the foot-end. In this case spasms in the arms occurred later.

Hitzig writes: "In regard to the relations of the various parts of the cerebellum to vertigo, it now seems to be the general opinion that vertigo is always present when the basal parts of the worm, and especially its posterior portions, are involved."

Leube writes: "Similar to the results from experiments, patients with cerebellar affections suffer from vertigo. Usually it is absent in a quiet position of the body, but becomes very accentuated as soon as the patient sits up or walks. If the vertigo is very pronounced, involuntary attempts may result in producing forced movements, which balance the disturbance of the locomotion sense produced by the lesion in the cerebellum. This may even appear in the conscious state, and in patients who are perfectly conscious may be present without vertigo. These forced movements are to be regarded as an irritative symptom, and if they take the form of a rolling about the long body axis, as a symptom of affection of the pontine peduncle. The peculiar forced movements of the eyes described by Nonat, where one is turned down and out while the other looks up and in, also point to this lesion.

"A second symptom of cerebellar disease is disturbance of co-ordination. Walking is staggering, wavering, like that of a drunken person. The feet are put down abruptly. Standing on one leg or with closed eyes is impossible. The wavering, however, does not necessarily need to become more pronounced on closing the eyes. It may, in fact, cease, as opposed to the ataxia of the tabetic. In lying down, the patient is able to perform definite movements. The muscular sense and sensibility are intact and the tendon reflexes normal. The ataxia is generally limited, in disease of the cerebellum, to the legs and trunk. In the vast majority of cases cerebellar ataxia means an involvement of the worm. Occasionally nystagmus is present; headache and vomiting are sometimes pronounced, more so than in other cranial affections."

In cases where closure of the eyes is not followed by increased wavering, or where this symptom ceased, we must assume that impressions conveyed along the visual tracts can be disregarded and that this tract may be injured or may be excluded from the preservation of the equilibrium.

The increase of the wavering on standing with the legs close together or on one leg, shows that the kinæsthetic tracts cannot be excluded, and that they are consequently still in

full activity. The preservation of the cutaneous muscular sense would only exclude a lesion of those paths going from the spinal cord to the cerebral cortex, not those of Goll's or Burdach's nuclei to the cerebellar cortex or of the direct cerebellar lateral tracts.

In disease of the pontine peduncles, the three centripetal equilibrium tracts are not involved. The consecutive forced rolling movements are performed without vertigo, as resulting from an injury to the centrifugal fibres which pass from the cerebellar cortex to the pontine ganglia and influence the pyramidal tracts.

The so-called cerebellar ataxia in which definite movements are performed while lying down, I cannot regard as such, but rather as an expression of an unconscious disturbance of the sense of position.

EQUILIBRIUM TRACTS IN THE MID-BRAIN.

The cerebral peduncles passing out from the pons enter anteriorly and externally in the hemispheres, and form, as trunks, a connection between the hind- and fore-brain.

The peduncle consists of a ventrally situated pes and a dorsally situated tegmentum, separated by the substantia niger. The white fibres of the pes consist of various fibre bundles coming from the cerebral cortex through the inner capsule, chiefly the pyramidal tracts. The tracts for the motor cranial nerves, which make a turn in the pons and medulla, and their nuclei, are situated to the inner side of these. The anterior cerebral cortical-pontine tract from the frontal lobe, and the posterior from the temporo-parietal and occipital lobes, which pass to the pons and cerebellum, are situated on the lateral side of the pyramidal tract.

The tegmentum contains on both sides of the median line, the red nucleus, which transmits the medullated fibres between the thalamus and cerebellum, which after passing through the red nucleus decussate and form the anterior cerebellar peduncle. Farther up in the basal parts of the thalamic region external to the red nucleus, there is a lenticular body, the corpus subthalamicum, containing nerve

cells, which gradually defines the cerebellar peduncle in the place of the substantia niger.

The main fibre bundle of the tegmentum is the lemniscus, a most important sensory tract. The main lemniscus conveys the tracts of the posterior columns of the cord centrally through the peduncles. This is the main sensory tract. It can be taken for granted that the lateral tract fibres of the lemniscus convey the impressions of the cutaneous senses, while those elements adjoining the posterior tract convey the impression of the muscular sense. The sensory spinal-cord fibres form in the medulla oblongata with the aid of the inter-olivary layer, the groundwork of the lemniscus. Most of the sensory nerve nuclei are in crossed relation with the lemniscus. This body is always well differentiated and can be followed into the anterior quadrigeminal bodies forming the deep medullary layer. Toward the brain, lemniscus fibres radiate with fibres from the red nucleus and the sub-thalamic region, to the thalamus, in part also from the sub-thalamic region through the lenticular nucleus to the cortex of the parietal lobe. This fibre radiation represents the main division of the lemniscus, which is to be designated as the median upper lemniscus. The lateral lower lemniscus travels from the upper half of the pons and from the upper olive, situated sometimes more distally in the level of the facial nucleus, to the posterior quadrigeminal body.

The roof of the mid-brain is formed by the quadrigeminal bodies whose anterior pair serve as the centre for the optic nerve, inasmuch as optic fibres radiate from the optic tract through the anterior arm to the anterior quadrigeminal body. On the other hand, internal fibres of the radiating corona arising from it, together with fibres originating from the thalamus and lateral geniculate bodies, pass through the posterior third of the internal capsule to the cortex of the occipital lobe. Anteriorly the quadrigeminal bodies are in relation with the nuclei of the oculomotor nerves. Fibres presumably pass from the posterior quadrigeminal bodies to the cerebral cortex. Fibres of the deep medulla of the anterior quadrigeminal bodies pass in a radiating manner internally to the gray substance of the aqueductus Sylvii. On

the ventral side of the posterior long bundle they form the fountain-like decussation.

The bundle of the fountain-like tegmental decussation from the mid-brain to the formatio reticularis and finally to the anterior column of the medulla, without doubt conveys optic reflexes to the organs of motility. Consequently, a conformity between the movements of the extremities and visual impressions can be produced by reflex paths. The very well pronounced longitudinal fibres in the formatio reticularis, which Bechterew has called the central tegmental tract, are regarded by him to be related to the function of bodily equilibrium on account of their certain relation to the lower olive.

The anterior quadrigeminal bodies as well as the lateral geniculate bodies are intimately associated with the visual function. Optic impulses pass in the ganglia of the former to the motor sphere. Irritation of the lower quadrigeminal bodies produces ocular movements, and movements of the extremities of the opposite side owing to the immediate relation of the posterior quadrigeminal bodies, by means of the lateral lemniscus and fibres of the trapezoid body, to the anterior acoustic nucleus on the one side and the reticulate tegmental nucleus and the pontine nucleus on the other.

The aqueductus Sylvii is limited by the rather thick layer of gray substance, the central cavity gray which extends from the commissura mollis of the third ventricle to the pyramidal decussation and contains the nuclei of the cranial nerves and, in the mid-brain, those of the oculomotor and the trochlear nerves. Longitudinal fibres pass below and externally from this central gray as a continuation of the anterior tract ground bundles, as the posterior longitudinal bundle which, coming from the region of the infundibulum and anterior process of the thalamus, passes into the formatio reticularis. In addition, the posterior longitudinal bundle contains communicating fibres with the various cranial nerve nuclei.

Destruction of the quadrigeminal bodies produced blindness and reflex immobility of the pupils by involving the

reflex arc between the optic and the oculomotor in its optical part. A direct communication between the anterior corpora quadrigemini and the nerve nuclei of the ocular muscles has been anatomically demonstrated.

In addition, destruction of the corpora quadrigemini produced ataxia, especially disturbance in balancing of the body, probably from a result of injury to the co-ordinating tracts which are indirectly in relation with the quadrigeminal bodies. Centres for the stomach have been found in the corpora quadrigemini, also vasomotor fibres.

Siebenmann in his investigations on tumors of the midbrain, especially of the corpora quadrigemini and tegmentum, speaks of this fact, of interest to the aurist, that vertigo on lying down was absent in every case. It seems that it only appears to enter into the composition of the clinical picture, and only in one form is a part of the symptom-complex of ataxia—namely, uncertainty of gait, the Romberg phenomenon, which must be separated from true vertigo.

Bechterew cites a number of cases in which vertigo was observed in disease of the third ventricle. The same author remarks that to the uninitiated observer it is almost impossible, from the appearance, to guess whether, in the particular animal experimented upon, the olivary body and semicircular canals or the central gray substance of the third ventricle have been affected. The cerebellum must be regarded as a central organ of the bodily equilibrium, while the olivary body and semicircular canals and the central gray substance of the third ventricle represent peripheric organs which serve as a region for certain centripetal impulses. They may be considered as the peripheric organs of equilibrium.

Bechterew regards the third ventricle as a structure similar to the labyrinth in which sensation of movements is perceived from the pressure of the liquid exerted upon the walls. If the inner surface of the funnel on both sides were divided into five similar triangular fields, starting from the apex below and spreading out above, the following conditions were observed on sections going through the various fields. Injury to the anterior segment from the optic recess upward

along the lamina cinerea and the floor, was followed by slight nystagmus internally, the pupils equally dilated, the snout extended forward, and the neck depressed. If the animal was let loose, it would describe irregular and unrestricted running movements.

Injury to the antero-lateral segments from the facial up to the foramen of Munro, was followed by lateral deviation of the eyes to the diseased side and nystagmus usually in the opposite direction, the corresponding pupil was dilated, the head depressed, the neck bent back toward the side of injury, rotation to the diseased side, and later moving in a forward direction with a certain tendency to deviate toward the healthy side.

Injury to the lateral segment caused lateral deviation of the eyes to the diseased side with the addition of nystagmus. Occasionally the eye on the diseased side would be turned upward, the corresponding pupil dilated and only react consensually. The head and trunk were turned toward the healthy side. Manége movements were toward the diseased side. There was occasional falling on the same side.

Injury to the posterior segment from the funnel toward the aqueductus Sylvii produced a convergence of the ocular axes downward and inward, violent nystagmus out and up, pupils moderately dilated, reacting to light. The head was not thrown backward. After a number of hours there were restricted movements forward.

Injury to the postero-lateral segment caused sharp turning of the head and trunk about the long axis toward the healthy side, the eye of the diseased side deviated up and out, the other down and in; the pupils were dilated at the maximum and did not react; on both sides there was distinct nystagmus in the opposite direction to the deviation; rolling movements of both eyes about the longitudinal axis in the opposite direction are not uncommon; forced position on the healthy side. If the injury is more pronounced, there are rolling movements about the long axis to the healthy side. Injury to the postero-lateral segment on the other side terminated the ocular deviations; turning the head and rolling movements; both pupils were very wide; there was

horizontal nystagmus, pendulum-like movements of the head and trunk, and disturbance of equilibrium. Electrical irritation caused the same symptoms in the opposite direction.

Bechterew assumes that the optic nerves put on a stretch by the movements of the eye exert pressure upon the wall of the third ventricle and thereby influence the nervous elements.

Presumably the tracts which have been spoken of in the discussion of the central course of the optic nerve, passing from this nerve to the third ventricle, were injured in Bechterew's experiments and prevented the cerebellum from receiving the visual impulses necessary for equilibrium.

Jacques Loeb demonstrated in the shark that a one-sided injury of the cerebrum, mid-brain, and cerebellum does not produce any disturbance of orientation; this, however, is surely produced by removal of, or section through, the base of the mid-brain. The parts of the medulla which join the mid-brain cannot be injured on one side only without producing disturbance of orientation; this is also absent if the section approaches the caudal half or quarter of the fourth ventricle. The forced movements directed toward the right, which follow section of the right half of the medulla oblongata about in the middle of the fourth ventricle, cease immediately on touching the animal. The sense of touch prevents them. The left eyeball is turned up, the right down; the right pectoral fin was rolled dorsally, the left centrally; at the same time it was somewhat elevated toward the head. In a quiet position the right side was entirely or nearly half dependent.

Jacques Loeb concludes that after one-sided injury to the mid-brain and medulla oblongata the causes of disturbances of orientation are qualitatively and quantitatively identical with those following section of the auditory nerve,—in this relation the auditory nerve corresponding to the part of the medulla oblongata on the same side and to the mid-brain on the opposite side. In other words, a section of the auditory nerve and medulla oblongata on the left side aurally from the auditory nerve, causes manége movements towards the left, just as section of the right mid-brain does. The manége

movements after section of the left mid-brain, and the rotations and associated changes of position following section of the right medulla can be completely retarded (inhibited) through the simultaneous section of the left auditory nerve.

As opposed to Ewald, this author mentions that after one-sided section of the auditory nerve in some animals, associated changes of position of the limbs and a corresponding anomaly of tension of the muscles appear. The tension anomalies of the bulbar muscles set in with the first innervation in animals which have been previously etherized.

The importance of the mid-brain and certain parts of the medulla oblongata for forced positions, movements, and associated changes of position of the eyeballs and sinews depends upon the circumstance that these parts contain components of the auditory nerve. After bilateral section of the auditory nerves in sharks these fish have a tendency to rise vertically in the water.

EQUILIBRIUM TRACTS IN THE CEREBRUM.

The sensory motor regions may replace the cerebellum to a certain extent. Thus their influence upon the preservation of the body equilibrium is assured.

The posterior roots, in addition to the trigeminal and vestibular nerves and ascending elements of the posterior and lateral tracts, their continuation in the lemniscus and the posterior cerebellar peduncles, and other paths to the cortex may be regarded as centripetal paths of the sensory motor sphere of touch which extends from both central convolutions and posterior segment of the frontal convolution and part of the parietal to the adjoining parts of the median surface of the hemispheres. Motor impulses are conducted principally by the pyramidal tracts with their spinal prolongations which join the root cells of the anterior horns; in addition, the centrifugal cranial nerves in the pyramidal tracts and in the accessory lemniscus, the fronto-pontine system, the corona radiata, the corpus caudatum and the putamen, the tracts from the cortex to the substantia niger, and finally from the radiating corona of the optic thalamus.

By disturbance in the region of the anterior cerebellar peduncle, the impressions of a lower order formed in the cerebellum about our position are erroneously transmitted to the cerebrum and vertigo is thus felt. By injury of the cerebral fibres of the middle cerebellar peduncle, the influence of the cerebrum on the cerebellum is disturbed, and the result of this can also be perceived as vertigo. By influencing the lemniscus tract up to the sensory motor zones, the voluntary realization of the centripetal sensations of position are prevented, and vertigo appears in the attempt at voluntary changes of position. Injury of the sensory lemniscus tracts up to the cerebral cortex leads, on account of the proximity of the pyramidal tracts, immediately to motor symptoms. Owing to the extended distribution of the sensory motor regions, an injury will cause erroneous conceptions about positions in space and general brain symptoms, especially loss of consciousness.

BY ALL OF THESE DISTURBANCES THE UNCONSCIOUS CEREBELLAR PRESERVATION OF THE EQUILIBRIUM WOULD NOT BE PREVENTED.

On the other hand, circumstances which lead to general congestion of the brain suddenly increasing the pressure within the cranial cavity, or in the case of a different position of the original trouble causing a complicating affection of the cerebellum or of the sensory motor region, would also lead to vertigo.

The vertigo appearing in diseases of the cerebrum is associated with more or less complete loss of consciousness. The patient suddenly experiences obscurations (blurring of sight). However, false impressions about his relations to surrounding space do not occur. These attacks of vertigo represent the mildest form of the apoplectic insult and may appear in the most diverse cranial diseases (progressive paralysis, multiple sclerosis, hydrocephalus, tumors).

Hitzig differentiates between cerebral and cerebellar vertigo following tumors. Tumors which are accompanied with attacks of vertigo of an epileptiform character with or with-

out convulsions, are, with the greatest probability, to be looked for in the proximity of the motor region. The attacks of vertigo of the other class are characterized by a general congestion of the brain. As these attacks usually appear with headache and vomiting, they presuppose the existence of a sudden, general, increased intracranial pressure.

The cerebellar forms are distinctly different from these central attacks. The symptom is here characterized by its unusual severity, by the frequency and duration of the attacks, which generally are also characterized by the presence of apparent movements in a definite direction. These attacks need not be epileptiform nor of a congestive character. They may appear without convulsions, clouding of the sensorium, headache, or vomiting; though convulsions, unconscious as well as congestive attacks, are not rare in cerebellar tumors. Just as in the cerebellar attacks, they are not infrequently terminated by vomiting.

Destruction of the occipital convolutions has sometimes resulted in forced movements, injury of the frontal lobe, with disturbance of the bodily equilibrium. The tracts of the pons appear as paths for centrifugal impulses which are in direct relation with the visual act, as, for instance, that impulse which is necessary to ascertain the position of the ocular axes, of the head, and of the trunk in the different positions.

Gowers assumes that in severe attacks of aural vertigo the cerebrum may be involved from the cerebellum and that transient unconsciousness may be present.

If we consider these three sensory paths which serve to instruct us of our position in space to be pathologically affected, we may then differentiate between the symptoms of irritation and those of defect.

An irritant acting upon any part of the ocular reflex arc can, if it reaches the necessary severity, produce inferior ocular movements—nystagmus. On the other hand, one depending upon the kinæsthetic sense tracts may lead to ataxia of varying severity. If the point of attack lies in the peripheric sensory or motor nerves, the ataxia is not as pronounced as when the site of the lesion is higher up in the

spinal cord. The vestibularis has no centrifugal reflex arc. Its irritation, if it is sufficiently severe, always produces vertigo, which first acts upon the oculomotor nerves on the one hand and on the motor tracts on the other. Thus nystagmus and staggering are the only objective appearances of vertigo visible to the observer. Both depend upon a false and frequently unconscious representation of our bodily position.

We have seen that in movements of the visual field certain regular contractions appear which up to a certain degree, notwithstanding the motion, produce definite visual impressions. The nystagmus in vertigo is not inco-ordinate, atactic but quite consequential. If, for example, pressure is exerted upon the vestibule of the right external auditory canal, an impression is produced as if space turned toward the right (the body to the left); the eyeballs slowly follow the apparently moving visual field and return from the terminal position with a quick jump, or, if the irritation is more marked, they assume a position just as in the case of quick rotation in an angle according to which the contractions have taken place.

As an example of accommodation upon an apparently approached or distant space, we may consider the narrowing and dilatation of the pupils which has been observed in vertigo by Rumpf, Mendel, and myself, in an injury to the external semicircular canal. In the same way the static muscles bring the body in the position which, from the standpoint of the erroneous impression, is the right one.

Thus, Kreidl's crabs, whose otoliths had been replaced by iron ones, and upon whom a stimulus has been exerted by the electro-magnet, swam in a crooked direction sufficient to equalize the pressure upon the two sides; in other words they appeared to be swimming in a straight line.

An inco-ordinated atactic movement does not exist. Ewald's doves, with the labyrinth defect on one side, appeared to turn the head in accordance with the erroneous impressions transmitted from the one remaining labyrinth. If the doves exhibit atactic symptoms in their rolling movements, this depends upon a lack of tone which, in these

animals, is exerted upon the muscles. In man this muscular tone is absent. In man it is generally easy to distinguish between disturbances of vertigo and of co-ordination. Frequently the sensation of vertigo, as spoken of before, and an erroneous apparent position of the surrounding space are described. The vertigo often disappears on lying down, while the ataxia continues. On the other hand, in the horizontal decubitus the apparently inco-ordinated movements of the legs cease. The knee and heel experiments are definitely performed, and the other leg is brought with certainty into the position of the passive one. The apparent ataxia or irregular play of the static muscles is a struggle between the attempt to bring the body into an apparently correct position, and the effort to improve a position which is immediately recognized as false,—the struggle between voluntary and subcortical innervation, which Schmidt-Rimpler has described as typical nystagmus for the eyes.

It is impossible, in ordinary clinical observation, to separate this maze of movements. We have the experiments of Mach, previously quoted, to enable us to do this. Luciani's experiments have shown that part of this muscular activity arising from the cerebral cortex is consequently voluntary. After removal of the sensory motor cerebellar hemispheres, and of the gyrus sigmoideus, after removal of the cerebellum, Luciani has demonstrated that the compensatory movements which animals without a cerebellum are capable of, enable them to preserve the equilibrium in standing and walking and swimming, and depend upon the sensory motor spheres of the cerebrum, and that these may be separated from the syndrome of defect symptoms of the cerebellum—namely, the simple resection of the gyri sigmoidei, which represent the most important segments of this sphere.

In order to produce the immediate appearance of staggering and of nystagmus in cases of vertigo, the following different measures are at our command:

We may first increase the stimulus on the same sensory path which has heretofore been too weak for their production. This is very simple in slight subjective vertigo following fistula or irritation of the semicircular canal. Slight

pressure upon the fistula produces nystagmus and staggering if the very sensitive vestibular apparatus has not been injured. If no fistula be present, this can sometimes be accomplished by increased pressure in the auditory canal, which is conveyed through the fenestra to the internal ear. In other cases we must add the physiological to the pathological stimulus by causing movements of the head in the plane of rotation of the semicircular canal which is to be examined, thereby producing lymph currents or bringing the otoliths of the macula sacculi and utriculi out of their position of equilibrium. By walking straight ahead the macula utriculi may be excited; by bending the head sideways, the sacculi become irritated. Rotating the head takes place in the plane of the greatest part of the external semicircular canal. If the head be rotated about an axis of 45° deviation to the right shoulder, then the right anterior or superior and the left posterior nasal meatus are brought in the sphere of rotation. If the head be bent toward the left shoulder, then the left anterior, the left antero-superior, and the right posterior are situated in the plane of rotation.

Ocular vertigo in certain extreme ocular movements is frequently increased to such a degree as to lead to nystagmus. The vertigo, depending on muscular sense just as the vestibular vertigo, can possibly be increased by electrical irritation to the onset of visible symptoms. However, for each individual person the unusually variable irritation threshold and the strength of the current must be known, in order to allow us to say whether we have to deal with a pathological stimulus or hypersensitiveness.

The second path by which we may increase a too weak stimulus is that by producing an irritation upon one of the other of the three sensory paths spoken of, which together with the pathological stimulus suffices. This occurs in vestibular vertigo, as, for instance, in the erect bodily position, which of itself frequently permits the onset of vertigo, while the horizontal position, without any excitation of the static muscles, may check nystagmus. A turning of the eyes to the extreme angle toward the healthy ear may produce nystagmus in the milder forms of labyrinth vertigo.

I do not know whether attempts have been made to produce nystagmus and staggering in eye patients by kinæsthetic or labyrinth stimuli or by irritating the spinal cord through irritation of the eyes and of the vestibulum. They should be practised in such a way that those suffering from spinal or eye disease are rotated or perform one of the movements described above to irritate the labyrinth, or those suffering with spinal disease may become irritated by carrying prismatic or cylindrical glasses before the eyes. Kinæsthetic stimuli in those suffering from eye or labyrinth disease could be practised by Mach's apparatus for passive rotating by movements of falling water.

A second group of diseases leading to vertigo is that in which the principal centripetal tracts are defective. If only one is wanting, the other two compensate. Tabetic patients, as long as their malady is localized in the spinal cord, are able to find their position through the eye and the vestibule. If the eye is excluded, vertigo sets in.

Bickel divided the posterior spinal roots of the posterior extremities in the dog. After a short time both labyrinths and the cortical zones were removed. He concludes from his experiments that the fact that the atactic disturbances, after producing this injury to the sensory spinal roots, can completely disappear is not of great importance. If, on the other hand, in animals who have compensated for their ataxia the labyrinths are extirpated, then again ataxia supervenes, we must conclude that compensation of the sensory ataxia does not depend on degeneration of the nervous tracts, but that other organs, as the labyrinth and other sensory organs, have produced the compensation. It is very probable that the optic tract and corpora quadrigemini and the cerebellum are important factors in this.

Max Egger described a case of bulbar tabes with disease of the third, fifth, seventh, eighth, ninth, and tenth cranial nerves. Of the oculomotor, the branch to the left external rectus alone was paralyzed. There was total deafness; preservation of the patellar, ankle, and elbow reflexes. The right radial reflex was absent. There was no wavering on standing with closed eyes or on one leg. The gait was

normal, not atactic nor wavering even with closed eyes. If, however, the patient while walking straight forward altered the position of the head—for instance, if the head which had been previously turned toward the left side was turned to the right, she lost her equilibrium and fell toward the side to which the head was turned. Passive rotations are not perceived. There is no nystagmus and no rotatory vertigo. An inspection, however, of a turning apparatus suffices to produce immediate vertigo. In this case the kinæsthetic tracts were normal. Slow stimuli of the vestibularis and oculomotor caused vertigo.

Nearly complete exclusion of all three tracts can be assumed to take place in patients without a labyrinth while swimming under water. Breuer has described the remarkable sensations experienced by the deaf-mutes while swimming under water. An intense fear is felt, and even in only a few feet of water they swim directly underneath the surface without being able to raise the head by a simple movement.

A third and last possible means of producing violent nystagmus would be that in the pathological defect of one path an irritation of one of the others should take place. This could be artificially produced as follows: The blind must be rotated, or, according to Mach's precepts, their muscular sense must be deceived. Advanced tabetic patients in whom the irritative symptoms have disappeared and pure paralyses are present, should also be rotated, or should be removed as described before, or by an improper glass be deprived of the use of their eyes. At this point should be mentioned the clinical observations of Ménière's symptoms in tabes, which have been observed by Maris and Walton fourteen times in twenty-four cases, after the progress of the disease had affected the nucleus of the vestibularis.

Should we, finally, regard the various combinations, we may say that the stimulus must have a certain strength if it is to produce vertigo through one of the three sensory paths, and that weaker stimuli in two different sensory paths may be combined to produce a more permanent result.

Further, in the absence of two sensory paths, the usual

positions and changes of position are sufficient to produce vertigo.

The site of the injury can vary according as the tracts are affected inward from their peripheric terminal organs to the points where the fibres leave them to communicate amongst each other. This location is in the middle part of the cerebellum (the worm), where Deiter's nucleus and the vestibularis send communicating fibres to the oculomotor nuclei and to the anterior horns of the spinal cord, and all three tracts are in communication with the cerebellum.

The true rotating vertigo is probably to be referred to the ocular and vestibular paths; the other erroneous conceptions of our bodily position may be caused by these as well as by the kinæsthetic paths in the most varying combinations.

The experiments to increase a slight degree of vertigo up to a grade of visible symptoms—namely, wavering and nystagmus—can, under certain circumstances, aid in making a diagnosis.

If one of the three paths can be excluded without increasing the vertigo, then it is useless and paralyzed. If the vertigo is thereby made less, then it is the site of the lesion. If the vertigo is made greater, then it is necessary and useful as a compensating agent and is consequently little damaged.

Increasing the stimulus does not aid us in making a diagnosis of location. On the other hand, in order to determine the site of the morbid cause, certain accessory symptoms should be investigated. For the eyes, the appearance of double images; for the ears, tinnitus and loss of hearing; for the spinal cord, reflex paralyses or increased paræsthesia, sensation of touch, sensation of pressure, sensation of pain, localization, temperature sense, power, consciousness of position of the extremities, and stereognostic perception.

REPORT ON THE TRANSACTIONS OF THE SECTION ON OTOLOGY OF THE NEW YORK ACADEMY OF MEDICINE.

By Dr. JOSEPH KENEFICK.

MEETING OF OCTOBER 9, 1902, JAMES F. MCKERNON, M. D., CHAIRMAN.

Presentation of Cases.

Dr. THOMAS J. HARRIS presented for Dr. PHILLIPS a case of **latent healing of extensive mastoid wound treated by means of skin graft.**

The patient, W. W. W., was first seen in February, 1901, complaining of general mastoid symptoms, the point of interest in the case being the rapid development of these symptoms. The attack set in on Wednesday; on Thursday a complete paracentesis (internal Wilde's) was performed; the following day the mastoid symptoms were so severe that the patient was sent to the hospital, where the ice coil was applied without effect. The next Monday a mastoid operation was performed and revealed extensive bone disease with exposure of the lateral sinus and brain. Microscopic examination showed the presence of streptococci. The subsequent history of the case is, that since this operation in 1901, three other operations have been performed, each time some diseased bone being found. The last operation was in April, 1902. In August of this year skin grafting was decided upon, and healing took place except in the upper portion of the wound. Ten days ago a second skin graft was made, resulting in almost entire healing.

The case is interesting as illustrating the assistance of skin grafting in latent healing of mastoid wounds.

Discussion: Dr. DENCH thought the method of healing as advocated by Dr. Phillips and illustrated by the case presented

was very successful, and was a valuable addition to the treatment for inducing healing in old mastoid wounds. He had conceived a plan of filling the wound with blood and allowing the clot to organize, afterwards placing a skin graft on top. Another question suggested in these cases is the relief of the deep pit which remains behind the ear. He referred to an article on this subject by a Vienna surgeon who advocated the injection of paraffin under the skin to relieve the depression. In his own experience he had found that in a number of mastoid wounds that would not heal there was still some necrosed bone present, and this being discovered, he did the radical operation at once, filling in later with a skin graft. He reported one case of skin grafting done at the time of the primary operation.

Dr. Brandegee said that he had pursued a method for filling mastoid wounds, which consisted of repeated instrumental irritation of the wound followed by loose packing with gauze and balsam of Peru. The irritation caused free bleeding; granulation followed; repeated irritation gave rise to more bleeding, followed by more granulation tissue formation, and so on, the wound gradually filling. He reported a case treated in this way in which the result had been satisfactory.

Sarcoma of the middle ear and mastoid. Dr. Dench presented the case of a child one and a half years old, who had come under his care three weeks ago, giving a history of having had a slight watery discharge from one ear for ten days. Examination of the eyes showed paralysis of the right external rectus muscle. The canal of the ear was filled with a tumor covered with thin epithelium. This bled easily, and a small piece was detached. The report of the pathologist showed that the tumor consisted of simple granulation tissue covered with epithelium. The child was sent to the hospital, and two days later the typical mastoid operation was done. On exposing the bone over the mastoid there was found a cauliflower-like mass occupying the region of the antrum. This was removed and the bone was found to be softened in every direction from the site of the growth. All soft bone was removed, and in so doing the dura over the roof of the tympanum was exposed. There was free bleeding, and it seemed on examination that the growth extended to the apex of the petrous pyramid, and that involvement of the dura at this point accounted for the paralysis of the sixth nerve. The growth was at first thought to be benign, but further examination showed it

to be an epithelial sarcoma. The child has since done well, the wound has closed, and there has been some improvement in the power of the sixth nerve. There is, however, evidence of recurrence of the growth at the tip of the petrous pyramid and in the canal. A micro-photograph of the growth was shown. In regard to the future of the patient, Dr. Dench expressed the opinion that it would probably die; however, he has decided, if the patient's condition continues as at present, to make a thorough extirpation of the growth by a modified Gasserian ganglion operation. He had done this on the cadaver and found the operation to be simple and to give a good exposure of and free access to the upper surface of the pyramid. It is also his intention to tie the common carotid to cut off the blood supply to the part and thus retard the growth, the method of cutting off the arterial supply having been found valuable in treating new growths in the nose and naso-pharynx.

Dr. HORN presented a case of **epithelioma of the tragus.** The patient, B. R., aged forty-eight, female, four years ago noticed a small abrasion over the tragus followed by ulceration. This would heal about every two weeks and then recur, and the process of healing and ulcerating has continued until about four weeks ago. There is no noticeable glandular enlargement. Various local applications have been tried without permanent result. Microscopical examination has not been made.

Discussion.—Dr. DENCH asked if there was a tubercular history.

Dr. HORN replied that there was not.

Dr. DENCH said that, granting the growth was malignant, the history was favorable for removal. He had previously reported three cases of malignant growth of the auricle, one involving the cervical glands, in which the growth and glands were successfully removed. In another case, without glandular involvement, the excision of a triangular piece, embracing the growth, with suture of the edges of the wound, gave relief. In a third case resembling the one presented by Dr. Horn, the growth was successfully excised. He considered the results in these cases exceedingly satisfactory if prompt surgical measures were instituted.

Dr. HARRIS presented a case of **continued mastoid pain after operation.** The case was presented for diagnosis, the following history being given: Young woman, twenty-four years old, was first seen in April, 1902, and kept under observation for two weeks. At that time she complained of pain over the region of

the mastoid and some elevation of temperature. There was a history of old suppurative disease, but there had been no discharge for some time previous. The drum was entirely absent. The patient was operated on in April, and no diseased bone was found nor any granulation tissue; the wound healed almost by first intention. For a short time after the operation all pain disappeared from the mastoid, but she complained of pain above and higher up; this latter has persisted until the present time. The patient has been treated by Dr. Leszynsky with electricity, tonics, and KI. On recent examination it was found that pain was present *over* the mastoid along the line of incision. This pain comes on twice a week and is so severe that the patient seeks relief from anodynes. She is well nourished, able to work, and eats well, except while the pain is present. At the time the pain comes on there is a watery discharge from the ear. There is also tenderness over the upper portion of the temporal bone and over the mastoid; also when the pain is present over the mastoid on the operated side it is also present on the other side where there has been no trouble at all.

Discussion.—Dr. DUEL asked if there was any eburnation of the bone found at operation, and if there had been a previous purulent condition.

Dr. HARRIS answered yes to both questions.

Dr. DUEL asked if the pain was not constant.

Dr. HARRIS replied that it was not constant, and that for two months following operation there had been no pain at all on deep pressure over the mastoid; the pain was referred higher up.

Dr. DUEL asked if there had been any examination of the fundus.

Dr. HARRIS replied that there had not been such examination.

Dr. DUEL then said that he considered that an examination of the fundus was quite necessary in cases where there was eburnation of the mastoid and where the pain continued so severe and intermittent as in the case presented; he suggested that the source of the trouble might be deep-seated, or it might possibly be of an hysterical nature if all of the diseased area had been removed at the first operation.

Dr. FRANK N. LEWIS asked the condition of the reflexes.

Dr. HARRIS stated that the case was reported negative, except that the patient was somewhat reduced in health.

Dr. DENCH asked about the temperature; its height, was it constant? and was the patient sleepless on account of the pain?

Dr. HARRIS replied that the average temperature was 1 to 1.5° above normal; it was constant, and the patient could not sleep on account of pain when present.

Dr. J. OSCROFT TANSLEY referred to a case of Dr. Holt, of Portland, Maine, where great mastoid pain was complained of and the mastoid was opened. The pain continued and the temperature ran as high as 106° to 107°; this would be the condition in the mouth, the rectal temperature being normal. Later the condition would be reversed, the high temperature showing in the rectum while the temperature in the mouth was normal. Nothing at all was found abnormal on exposing the brain at a second operation, and the case was diagnosed and proved by subsequent events to be hysteria.

Dr. McKERNON asked if at any time there was tenderness in the upper part of the temporal bone and over the ridge.

Dr. HARRIS stated that this was the region referred to as being tender at all times.

Dr. McKERNON further asked if there had been any vertigo or chills.

Dr. HARRIS said no.

Dr. KENEFICK asked if the teeth had been examined.

Dr. HARRIS said no.

Report of cases and technique of procedure in establishing hearing for deaf-mutes. By MAURY M. STAPLER, M.D., Georgia. After reading the paper Dr. Stapler demonstrated the use of the "rarefier" on two deaf-mutes. He stated that the instrument was yet very new and experience in its use was wanting, but he desired to present it to the Section with a report of the cases where it had been used successfully, and expressed the hope that future experience in its use would further demonstrate its value.

Discussion.—Dr. McKERNON wished to know if this method of treatment was applicable to those cases where there was a relaxed condition of the upper and posterior part of the drum membrane, and if any results followed its use in old cases of otitis media catarrhalis chronica.

Dr. STAPLER replied that it could be used in those cases, and he narrated a case of his own in an elderly person who had been getting worse. He stated that after four days' treatment the hearing was restored to the degree of usefulness. This was the only case of the kind he had observed.

Dr. BRANDEGEE wished to know if Dr. Stapler had any statistics on the results of the rarefying treatment in tinnitus aurium.

Dr. STAPLER said that he had three cases in which the tinnitus was entirely stopped; the greatest duration of the condition had been in one case, one and a half years. Long-standing cases had not been affected. He did not know, in any of the cases, to what the tinnitus was due.

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